

LAKE OKEECHOBEE WATERSHED PROJECT

Modeling Sub-Team

Initial Alternative Array
April 4, 2017

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US Army Corps of Engineers
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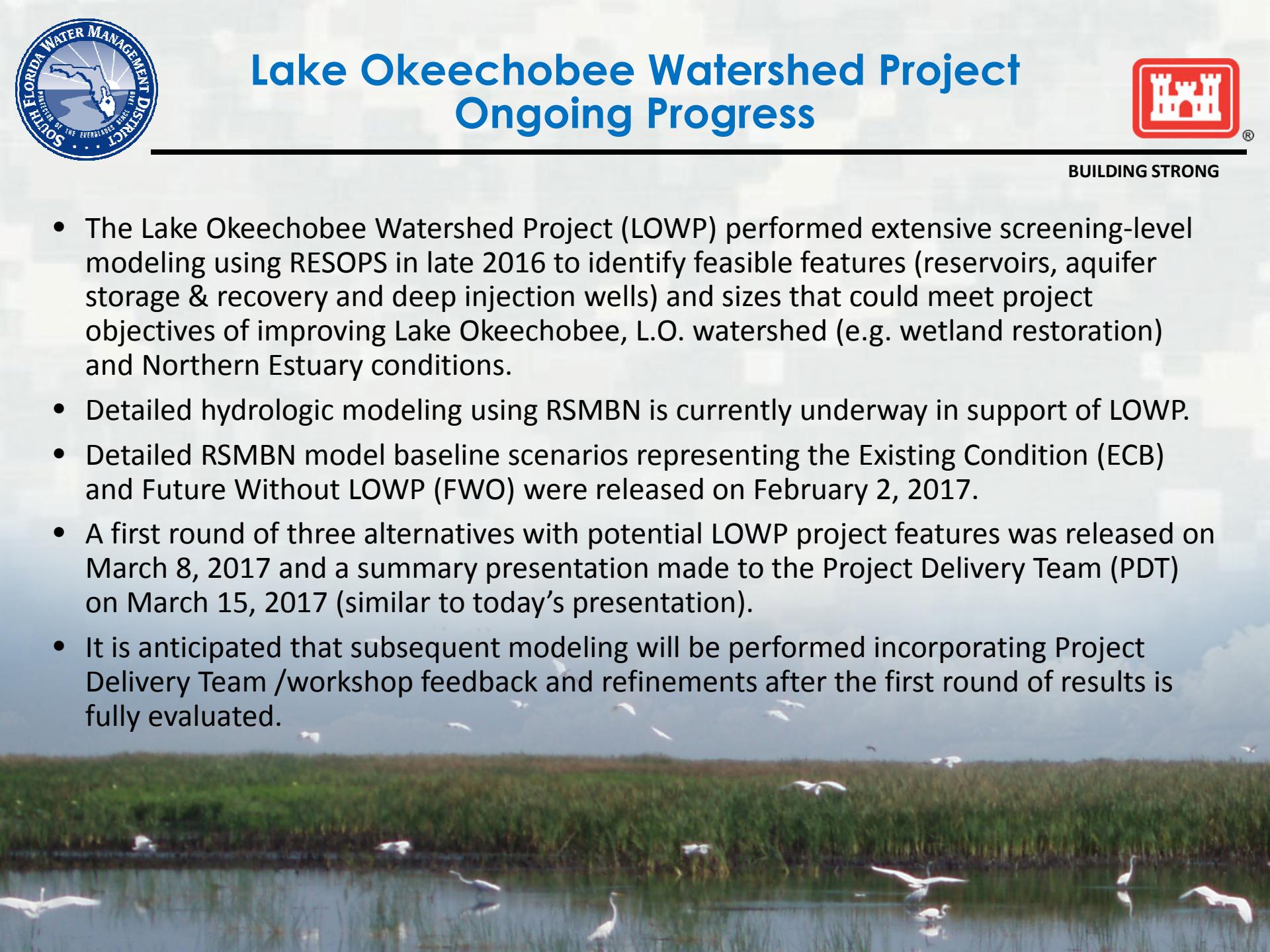
Lake Okeechobee Watershed Project

Ongoing Progress



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- The Lake Okeechobee Watershed Project (LOWP) performed extensive screening-level modeling using RESOPS in late 2016 to identify feasible features (reservoirs, aquifer storage & recovery and deep injection wells) and sizes that could meet project objectives of improving Lake Okeechobee, L.O. watershed (e.g. wetland restoration) and Northern Estuary conditions.
- Detailed hydrologic modeling using RSMBN is currently underway in support of LOWP.
- Detailed RSMBN model baseline scenarios representing the Existing Condition (ECB) and Future Without LOWP (FWO) were released on February 2, 2017.
- A first round of three alternatives with potential LOWP project features was released on March 8, 2017 and a summary presentation made to the Project Delivery Team (PDT) on March 15, 2017 (similar to today's presentation).
- It is anticipated that subsequent modeling will be performed incorporating Project Delivery Team /workshop feedback and refinements after the first round of results is fully evaluated.

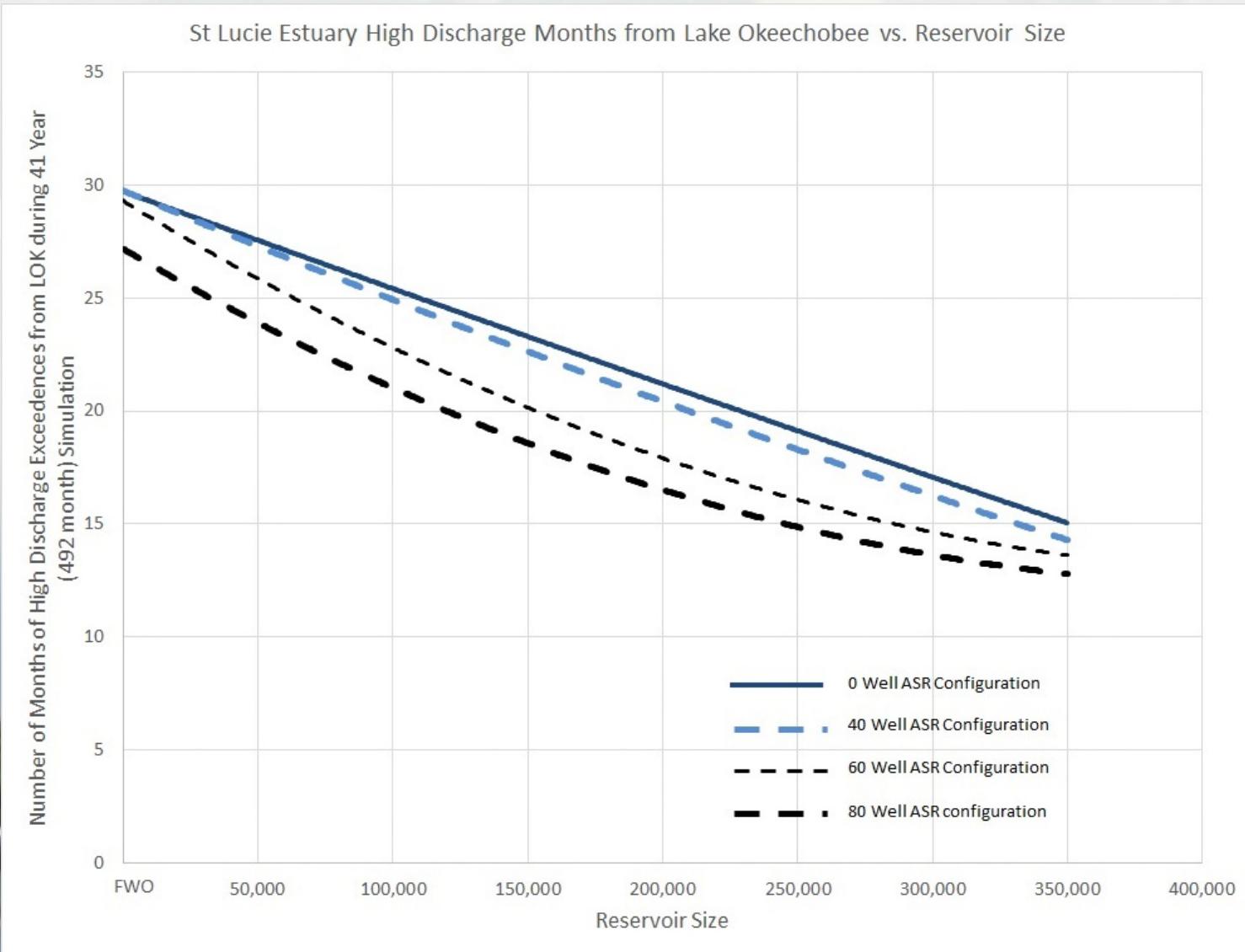




Background: Example Screening Modeling (RESOPS)



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Background: Regional Modeling Approach



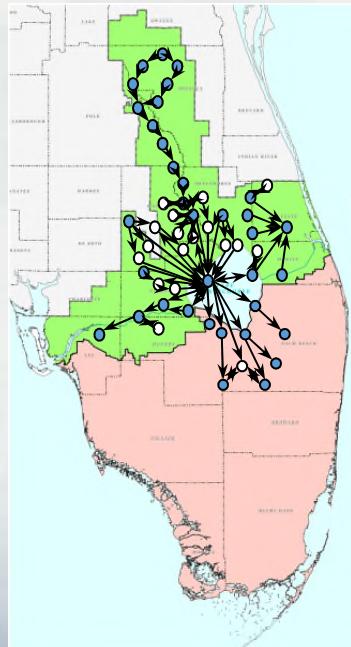
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- Climatic Input
 - Rainfall
 - ET
- Boundary Conditions

Period of record:
1965-2005



Scenario



- Project Features
- Operating Criteria



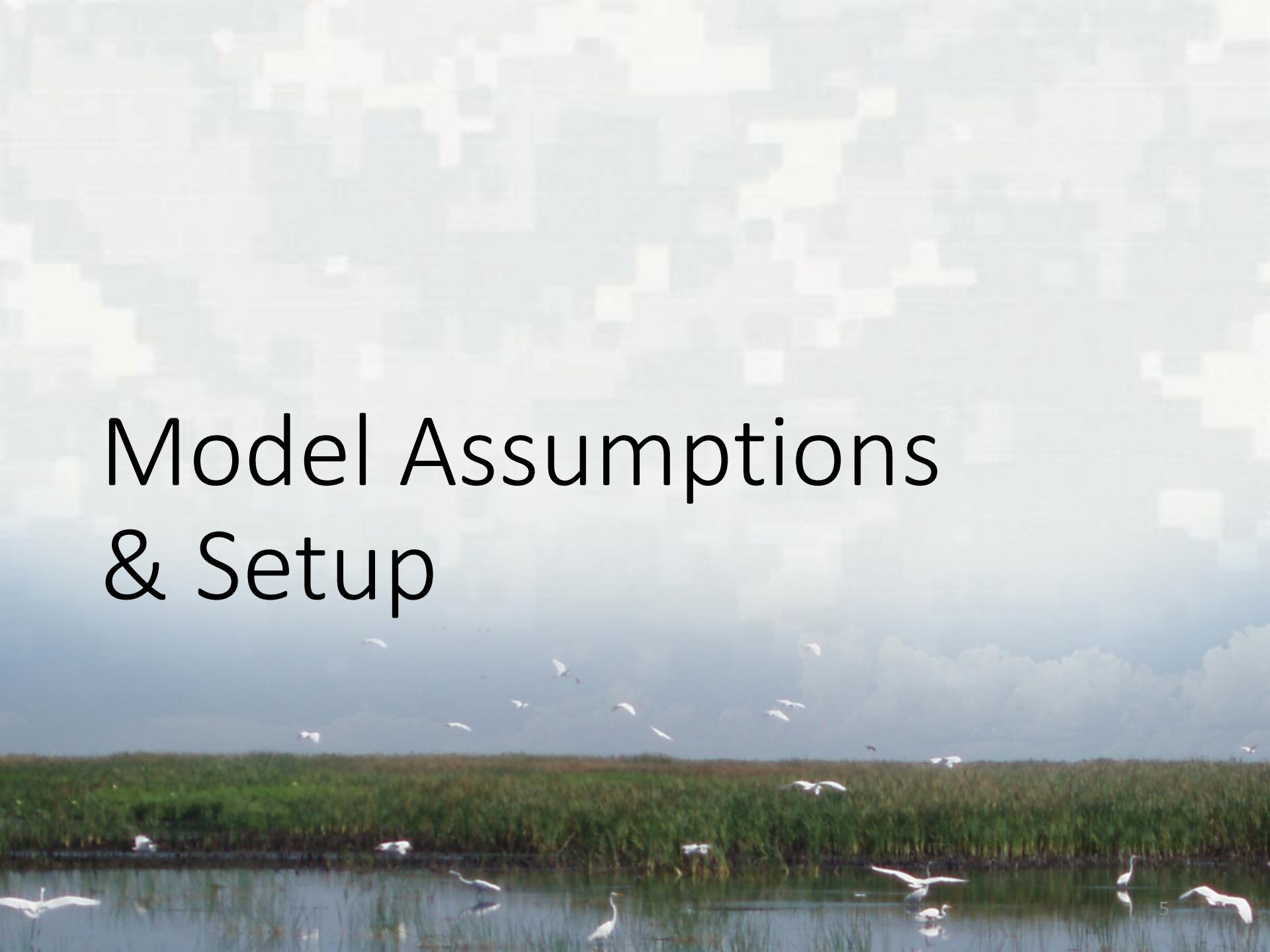
Model Output

- Daily time series of water levels, flows
- Demands not met



Evaluation
(Environmental,
Water Supply, etc...)

Model Assumptions & Setup

A scenic landscape featuring a body of water in the foreground, green reeds, and a large flock of white birds (likely egrets or herons) flying over a misty, cloudy sky.



INITIAL ARRAY OF ALTERNATIVES



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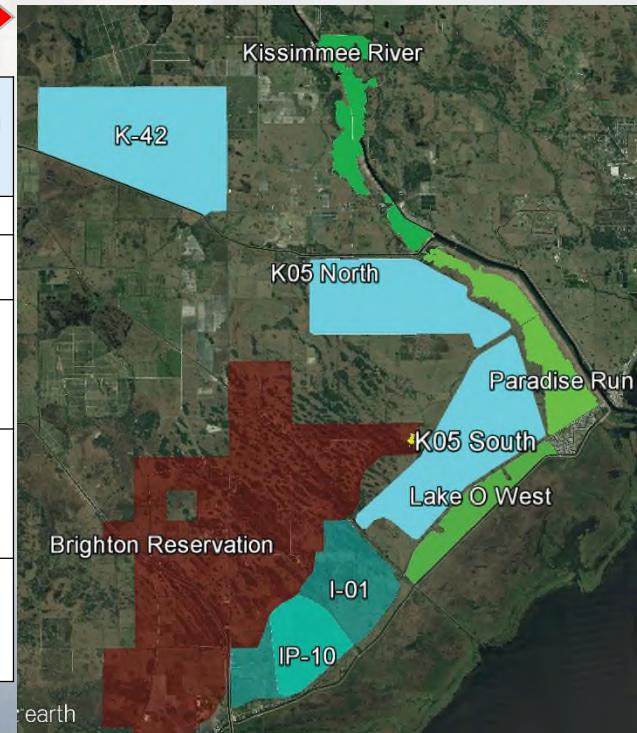
1st round of modeling and benefits calculation to optimize water storage and recovery for improvement in high and low lake stages and estuary releases,

2nd round of modeling and benefits calculation to optimize water management measures for improvement in undesirable regulatory discharges to northern estuaries along with wetland restoration measures

1ST ROUND OF MODELING

2ND ROUND OF MODELING

Alternative	Reservoir Component		# of ASR wells (assuming 5 mgd capacity)	# of DIWs (assuming 15 mgd capacity)	Comparable Wetland Components
	Reservoir(s)	Storage Capacity (acre-feet)			
No Action (FWO)					
Alternative 1	K05 (North and South)	258K	110	30-90	Kissimmee River Paradise Run
Alternative 2	K-05 (North and South) and K-42	408K	110	0	Kissimmee River Paradise Run Lake O West IP-10
Alternative 2b	K-05 North and K-42	264K	110	30-90	Kissimmee River Paradise Run Lake O West IP-10
Alternative 3	K-42 and I-01	254K	112	30-90	Kissimmee River Paradise Run Lake O West



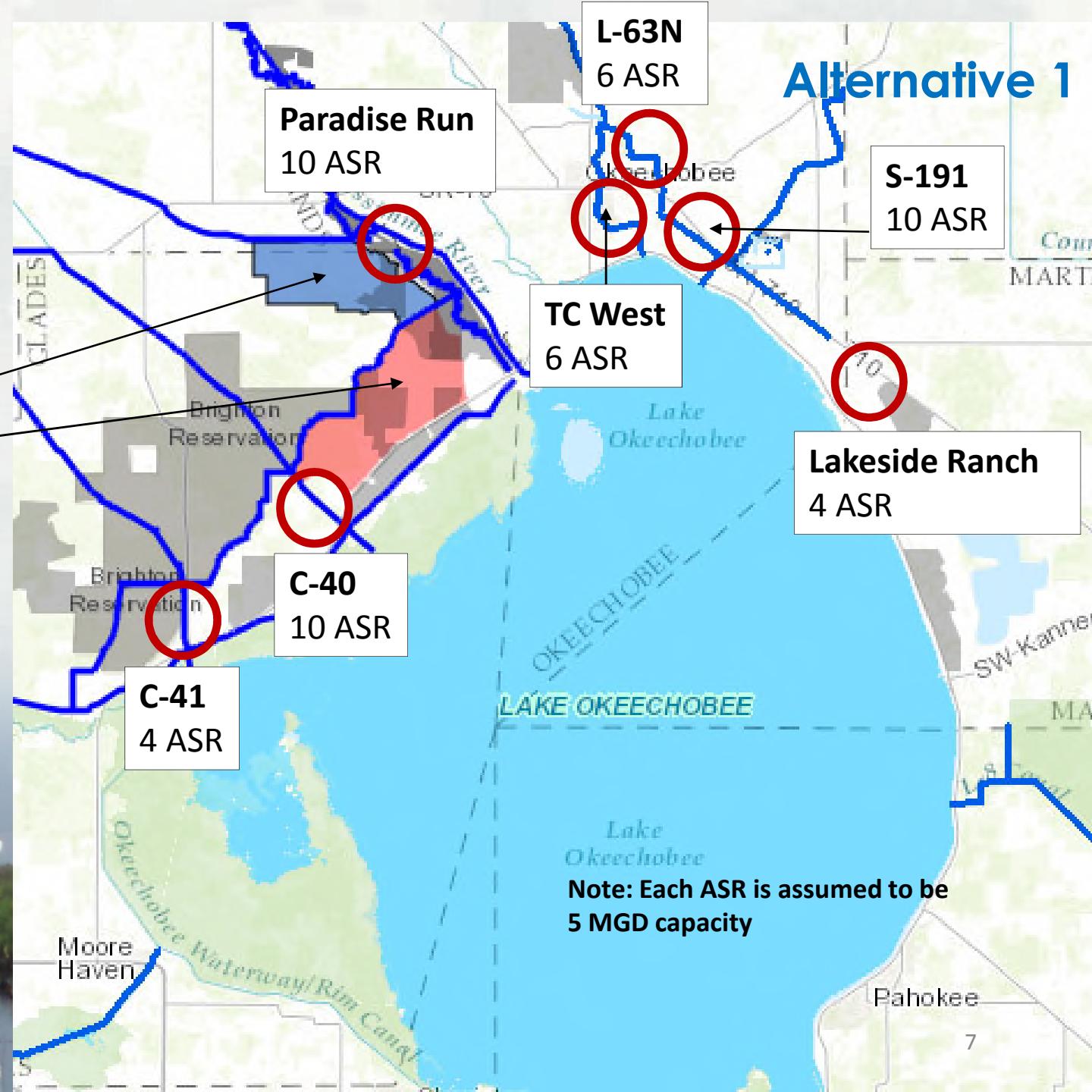
Note: Estimated reservoir storage capacity will be updated as additional engineering detail becomes available

Evaluated in 1st
Round of Modeling

ALT1 Assumes:
258 kac-ft storage at
K05 Reservoir
locations +
110 ASR as shown
(60 ASR co-located at
K05)

K05 North 7,605 ac
K05 South 9,625 ac

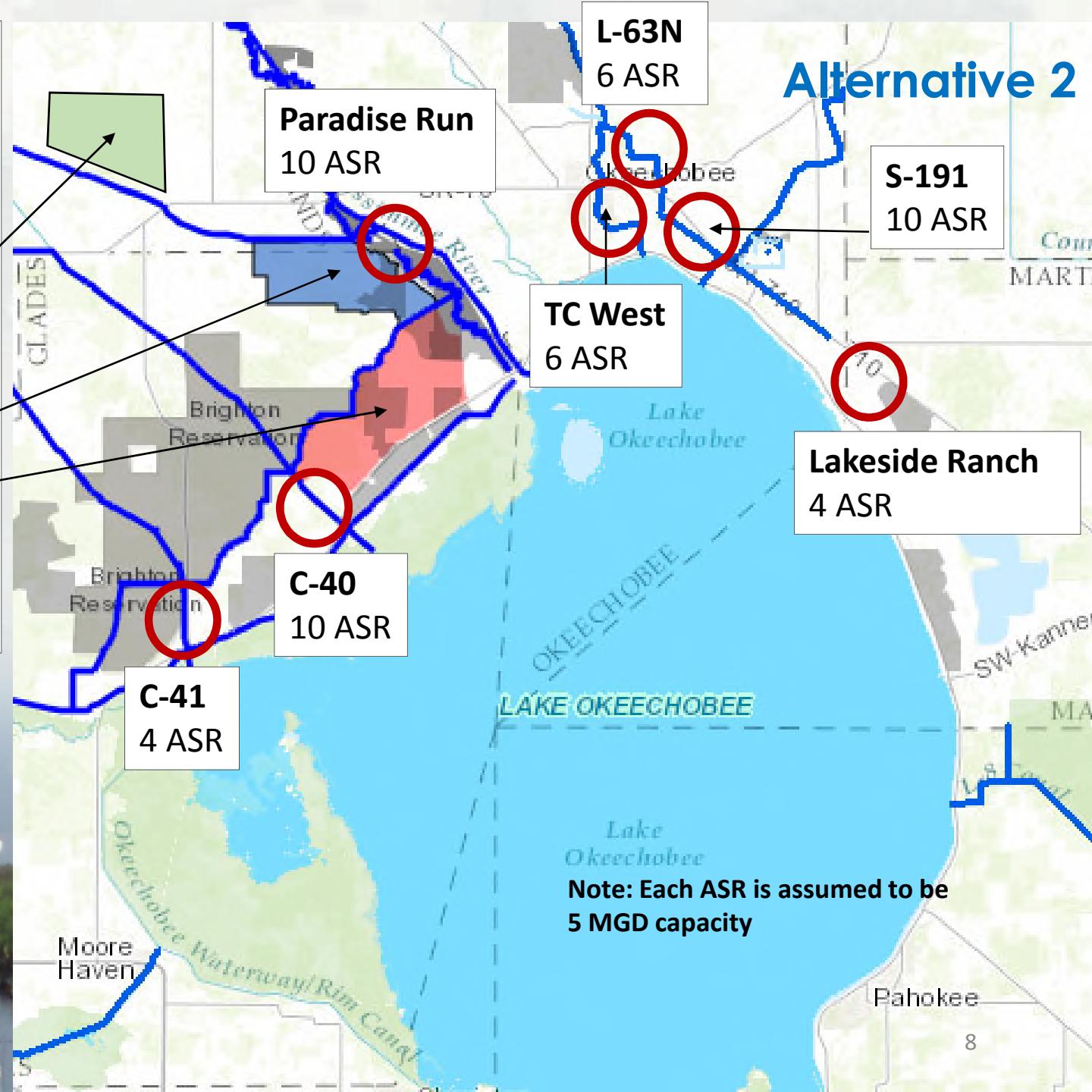
Reservoirs assumed
15 ft maximum depth



ALT2 Assumes:
408 kac-ft storage at
K05 and K42
Reservoir locations +
110 ASR as shown
(60 ASR co-located at
K05)

K42 9,984 ac
K05 North 7,605 ac
K05 South 9,625 ac

Reservoirs assumed
15 ft maximum depth



L-63N
6 ASR

Paradise Run
10 ASR

Alternative 2

S-191
10 ASR

TC West
6 ASR

Lakeside Ranch
4 ASR

C-40
10 ASR

C-41
4 ASR

Lake
Okeechobee

Note: Each ASR is assumed to be
5 MGD capacity

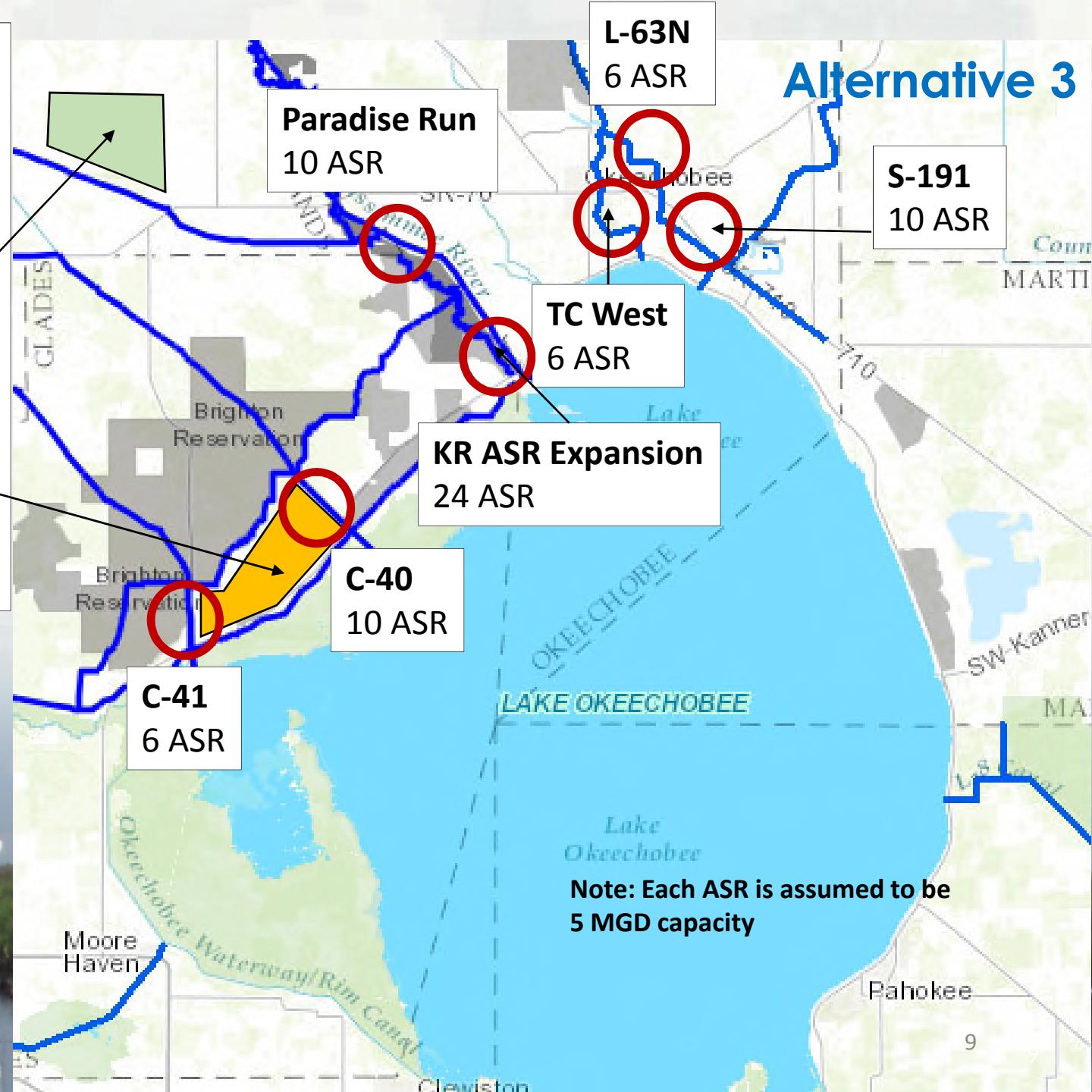
ALT3 Assumes:

254 kac-ft storage at
K42 and I01 Reservoir
locations +
112 ASR as shown
(40 ASR co-located at
I01)

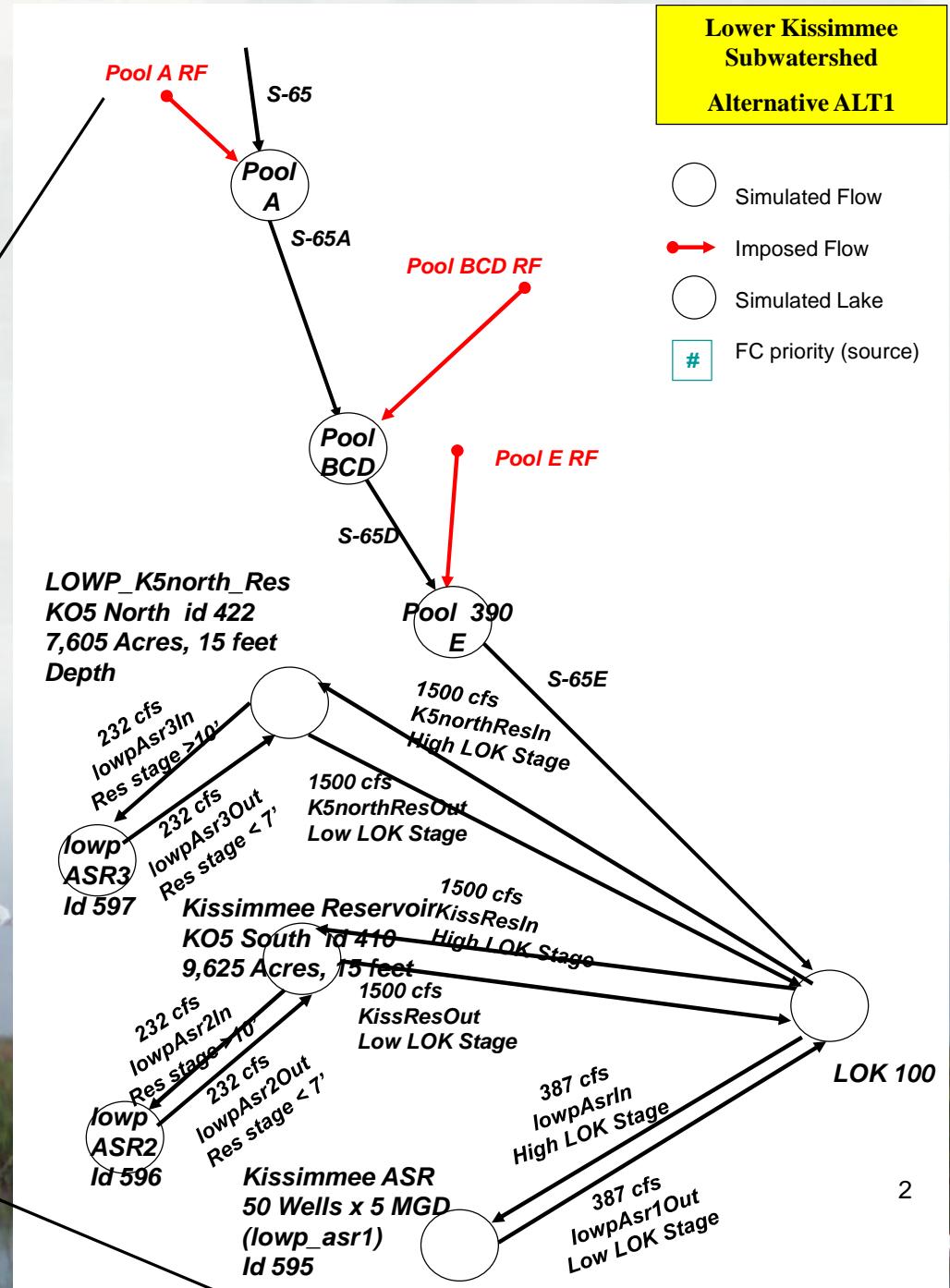
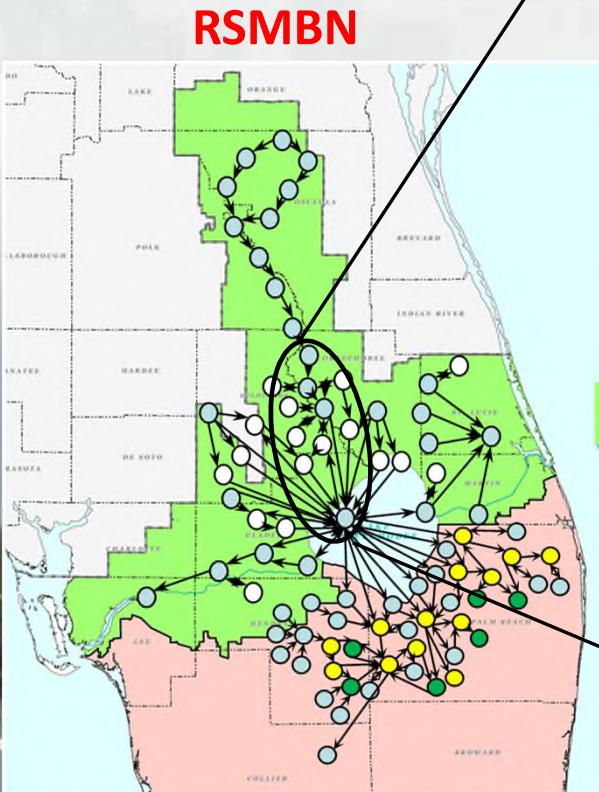
K42 9,984 ac

I01 6,965 ac

Reservoirs assumed
15 ft maximum depth



Example Modeling Detail Showing Assumed Lower Kissimmee Basin & Lake Okeechobee Inflow Routing for ALT1 Scenario





Operational Considerations in LOWP



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- In addition to infrastructure assumptions, there is a need to define rules for diverting water to and recovering water from reservoir and ASR storage.
- Also, as storage is added and system infrastructure capability is increased, it makes sense to develop optimized Lake Okeechobee schedule rules that work with storage and focus on the events beyond what storage or conveyance south can handle.

Note: The Yellow Book contemplated schedule changes for the same reasons





Lake Okeechobee Regulation Schedule in the RESTUDY (Yellow Book or D13R)



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Component F3

Geographic Region: Lake Okeechobee

Component Title: Lake Okeechobee Regulation Schedule (same as Alternatives 3, 4 and 5)

Purpose: Operating criteria for Lake Okeechobee that includes flood control, water supply (including releases to the Water Conservation Areas to meet estimated natural system needs), and Lake littoral zone and estuary protection.

Operation: Use current regulation schedule with the design modifications made in components A and GG and with the exception of eliminating all St. Lucie and Caloosahatchee regulatory discharges (except emergency releases - zone A, from Run 25).

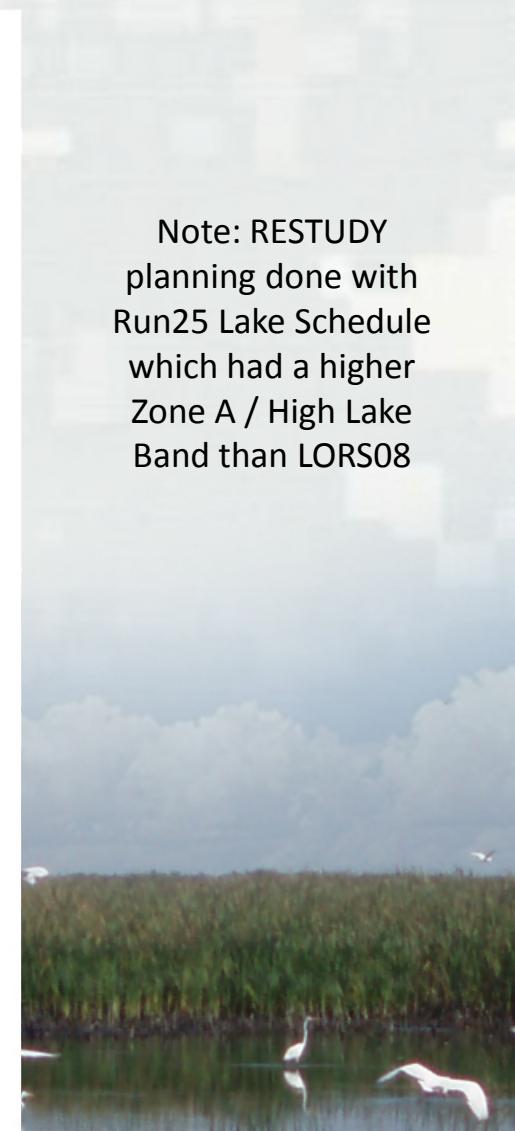
Design: Operational changes only. Modify the regulation schedule by eliminating all but emergency discharges to both the St. Lucie and Caloosahatchee Estuaries.

Location: Within existing boundary of Lake Okeechobee

Counties: Glades, Hendry, Martin, Okeechobee and Palm Beach

Assumptions and related considerations:

- 1) It is assumed that the implementation of other project components will reduce the frequency of high Lake stage events therefore reducing the need for regulatory releases to the St. Lucie and Caloosahatchee Estuaries.



Note: RESTUDY planning done with Run25 Lake Schedule which had a higher Zone A / High Lake Band than LORS08

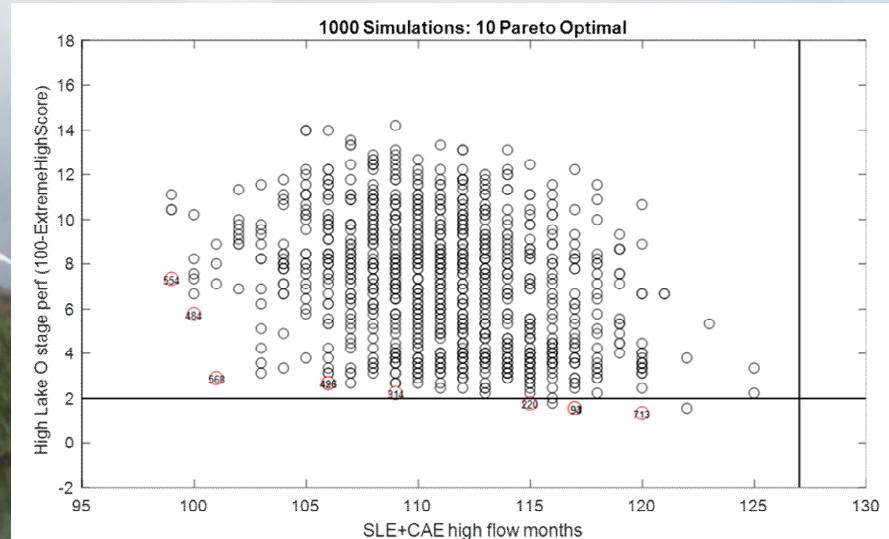


Operations Optimization for LOWP ALTs



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- Operational criteria for Storage (Reservoir and ASR) and Lake Okeechobee Regulatory releases were optimized to work with improved infrastructure contemplated by LOWP.
- Approximately 30 parameters affecting the Lake Okeechobee decision outcomes (e.g. “up-to” limits, classification of tributary conditions, etc...) along with a variety of storage diversion and recovery lines were analyzed.
- Constrained and unconstrained Latin Hypercube sampling techniques were used to explore up to 10,000 unique operational strategies per ALT.
- Selected operations were identified using acceptable performance criteria (e.g. Lake O and Estuary PMs) and Pareto analysis.





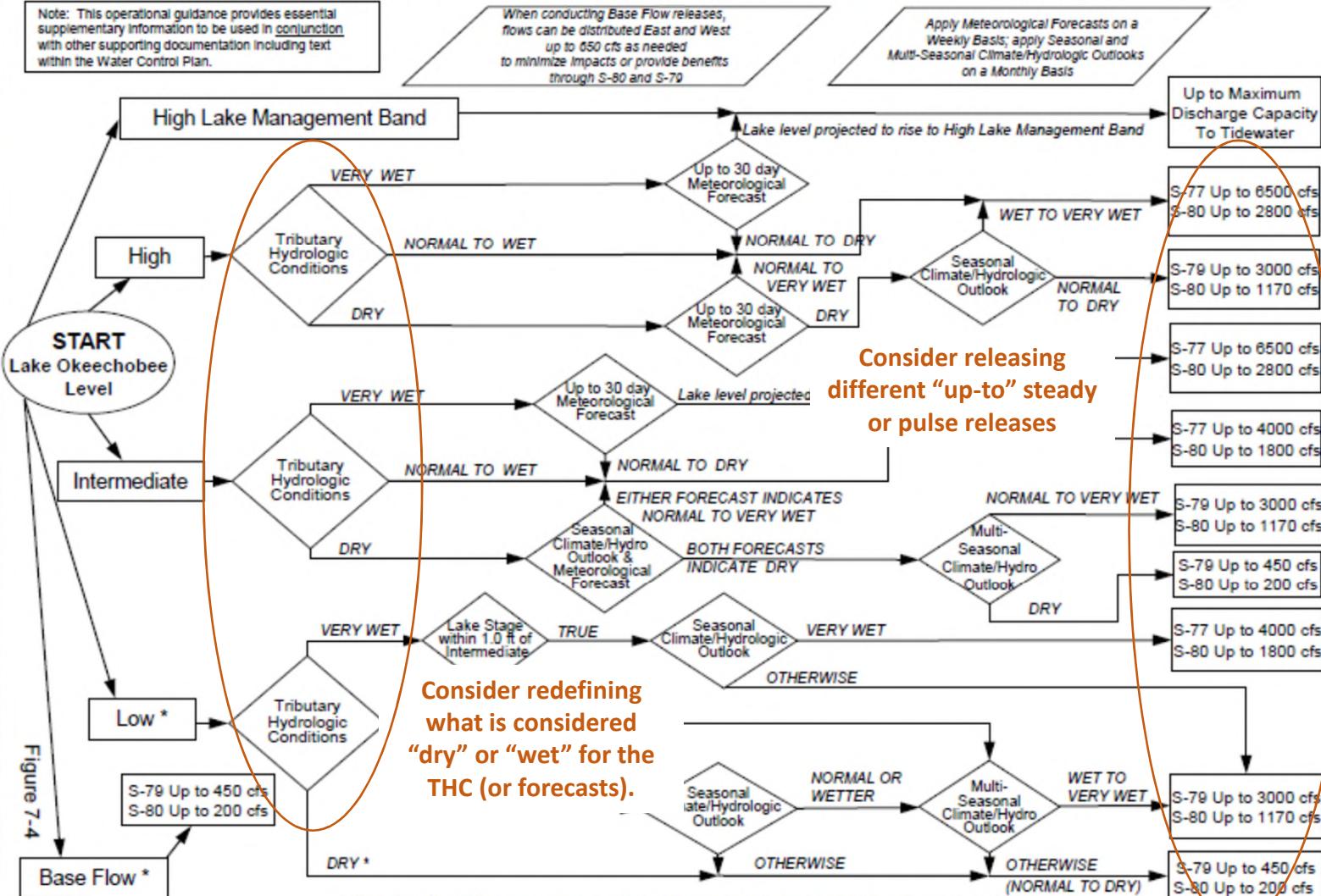
Operations Optimization for LOWP ALTs



DNG

For Example (~ 30 parameters): 2008 LORS

Part D: Establish Allowable Lake Okeechobee Releases to Tide (Estuaries)





Optimization Methodology

Procedure for Finding the Best-performing Operations

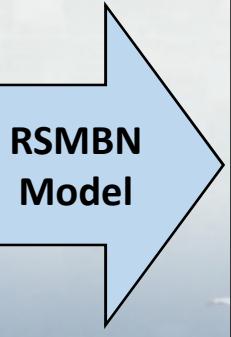


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Select key model input parameters & ranges

Generate 1000's of parameter sets (PARsets) via Latin Hypercube Sampling (LHS)

Without LHS, there would be ~ 2.4×10^{57} sets to analyze



Simulated Performance Measure Sets (PMsets)

One PMset for each PARset

Non-Dominated Sorting

Pareto-Optimal Solutions

Satisficing to meet MAPLs

Priority to Estuary PMs

“Best” Solution

RSMBN: Regional Simulation Model - Basins

PARset: one combination of input parameters for a single RSM-BN simulation

PMset: Performance Measure output set corresponding to a single PARset

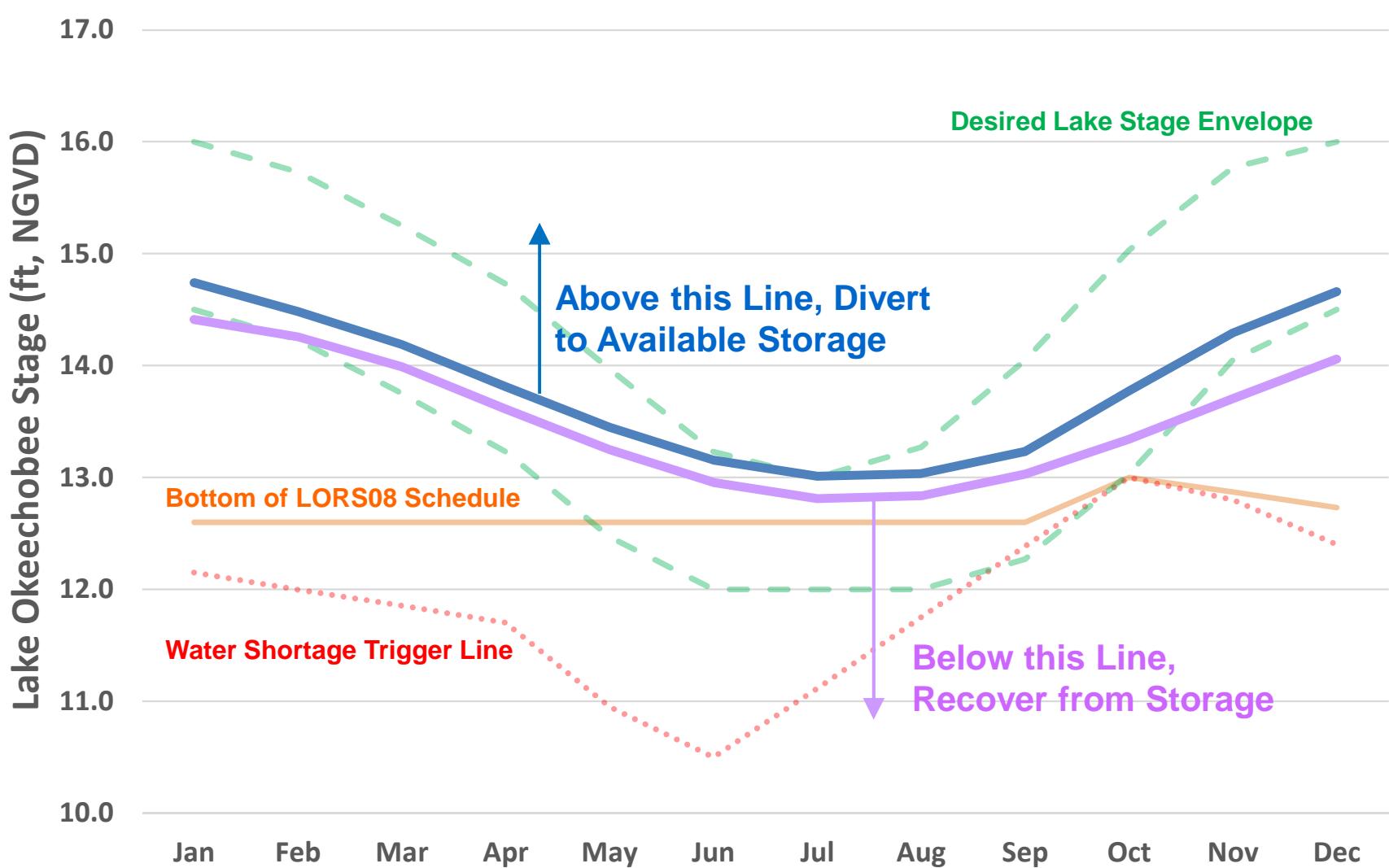
MAPL: Minimum Acceptable Performance Level

2		1175 of 2000 (groups f & g) simulations were Pareto Optimal (from Matlab script RMS_PM_ParetoSort.m [C. Neidrauer])																																	
3		11% of those 523 runs meet all 10 MAPLs (all but 3 from group f)																																	
4		MAPL	24	20	59	22	0.18	70	60	90	90																								
5	Index	Group	Sim	Phi	SLE3	Scor	SLE2	Scor	SLE	Aug1	CAE1	Scor	CAC	Scor	CAE	Avg	8	Worst	2000	Cut	LOK	H	S	LOK	Lo	LOK	Extra	LOK	SAV	Scor	Chara	Sc	Cyanobat	Epiphyte	Epipelon
38	7254	f	54	46.47781	25	18	100222.9	58	16	115287.3	0.072137	0.178739	77.85273	69.76558	91.79602	98.0488	1.7	1.175	1.2	1.475	0.875														
39	7255	f	55	180.7148	22	20	97141.65	60	14	112538.9	0.069743	0.171719	75.83457	72.11811	89.80045	98.8618	1.7	1.175	1.2	1.4125	0.8375														
40	7256	f	56	101.7667	24	19	97803.09	56	17	112028.2	0.072562	0.173222	77.51757	70.1273	91.79602	98.6992	1.7	1.175	1.2	1.45	0.8625														
41	7262	f	62	280.6276	23	21	100556.4	59	14	112155.7	0.07157	0.180534	77.17698	70.67841	89.57872	98.2114	1.7	1.175	1.2	1.45	0.85														
42	7264	f	64	179.4217	23	20	96052.38	58	15	107355.9	0.070476	0.171719	76.68616	91.57429	98.3618	1.7	1.175	1.2	1.3875	0.8375															
43	7266	f	66	179.4217	24	20	104468.9	59	14	111620.3	0.070188	0.178739	77.72616	70.54349	91.57429	98.2114	1.7	1.175	1.2	1.45	0.875														
44	7267	f	67	46.76961	24	18	98393.38	58	16	114785.7	0.0728	0.172907	77.92644	69.49436	91.55256	98.6992	1.7	1.175	1.2	1.225	1.475	0.8625													
45	7271	f	71	102.0585	23	19	102712.3	58	14	107774	0.071123	0.180221	77.39877	70.60285	91.35256	98.2114	1.7	1.175	1.2	1.4625	0.8375														
46	7272	f	72	102.2103	24	19	99821.3	59	14	108993	0.0697	0.171719	76.72442	71.98972	91.13083	98.8618	1.7	1.175	1.2	1.425	0.8375														
47	7278	f	78	45.81707	28	18	100831.2	57	17	109095.9	0.071845	0.171719	77.85273	70.14029	92.50466	98.6992	1.7	1.175	1.2	1.4375	0.85														
48	7279	f	79	13.55505	25	17	100401.4	59	15	108031.6	0.069842	0.17049	76.67678	71.60993	91.57429	99.0244	1.7	1.175	1.2	1.425	0.825														
49	7280	f	80	45.69672	28	18	106727.6	58	16	107713.2	0.071575	0.180221	78.00725	69.87949	93.12639	98.2114	1.7	1.175	1.2	1.45	0.8625														
50	7281	f	81	101.1059	27	19	100365.6	60	17	11373.3	0.072198	0.171719	76.45559	70.3071	92.90464	98.6992	1.7	1.175	1.2	1.45	0.8625														
51	7283	f	83	180.368	24	20	100037.9	58	14	109884.2	0.069642	0.1689	76.52447	71.1498	90.24391	99.2244	1.7	1.175	1.2	1.4125	0.825														
52	7284	f	84	179.2778	24	20	98976.05	58	16	114381.8	0.072316	0.180221	77.58042	70.49518	91.79602	98.2114	1.7	1.175	1.2	1.45	0.875														
53	7285	f	85	47.91487	25	18	97613.31	58	13	113129	0.070376	0.178479	76.1735	71.10751	89.80045	98.2114	1.7	1.175	1.2	1.4375	0.85														
54	7288	f	88	13.55506	26	17	103259.7	58	17	116374	0.073554	0.185566	78.3727	68.85687	91.57429	98.0488	1.7	1.175	1.2	1.475	0.8875														

Trusted Pa



Example Outcome: Operational Triggers for LOWP Storage Components



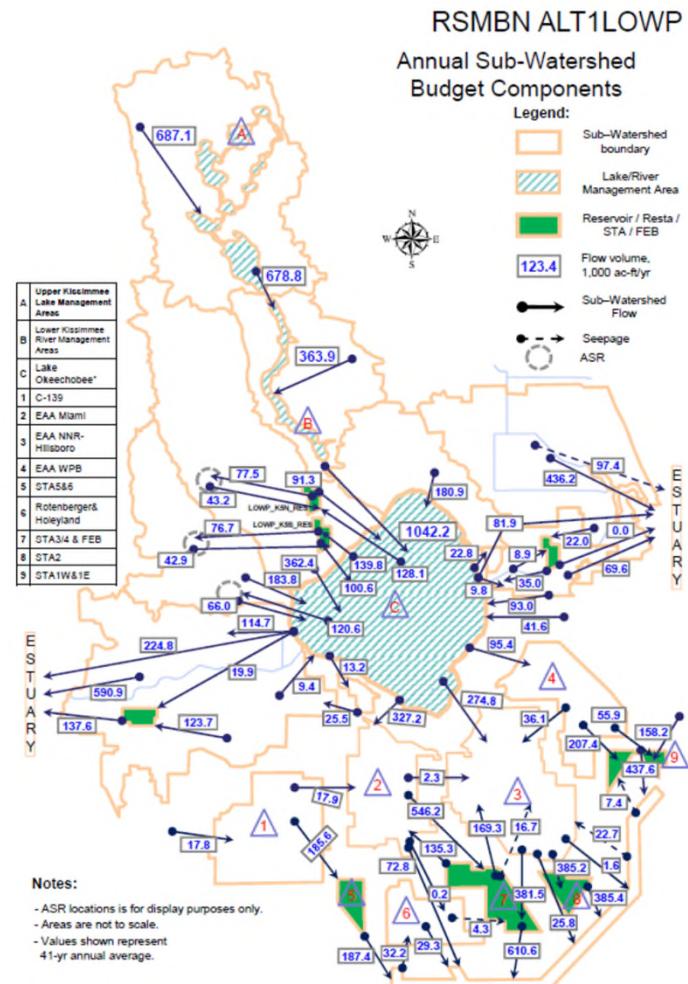
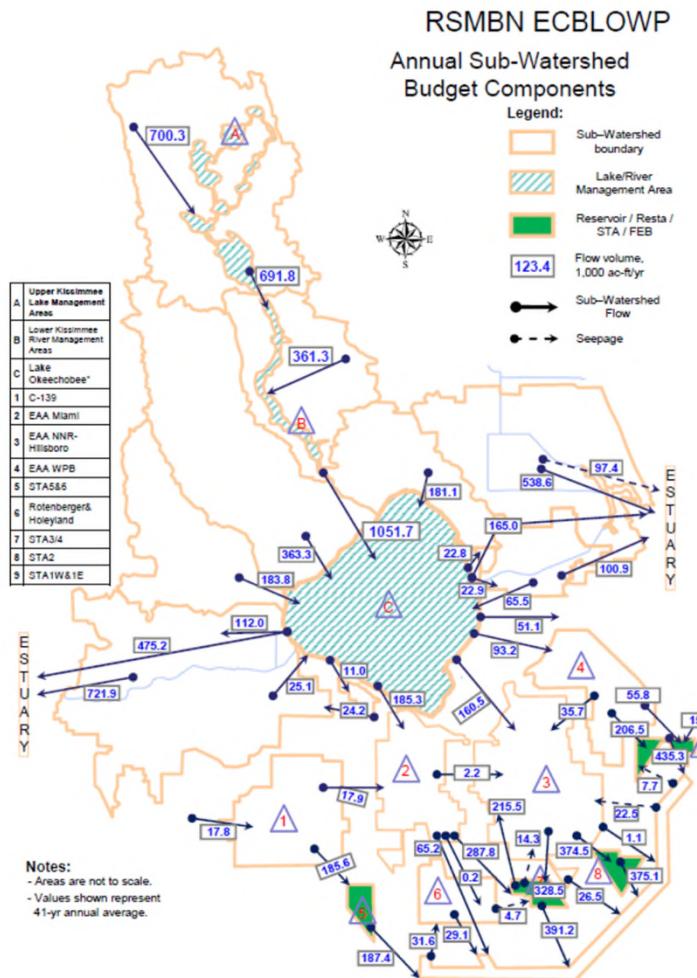
Model Results Summary



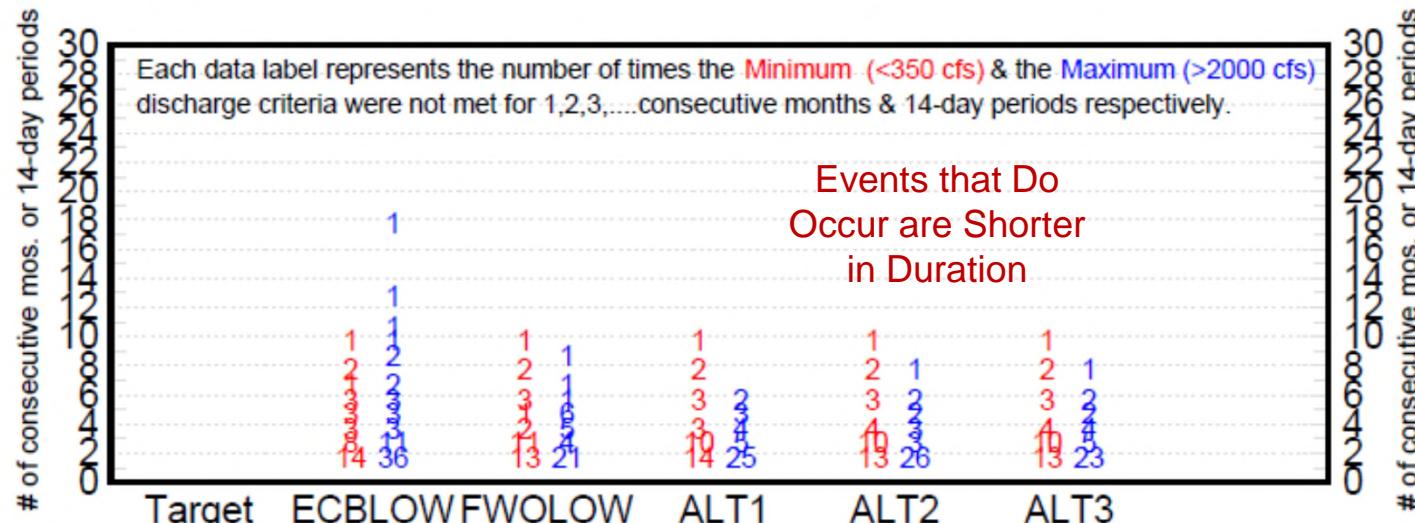
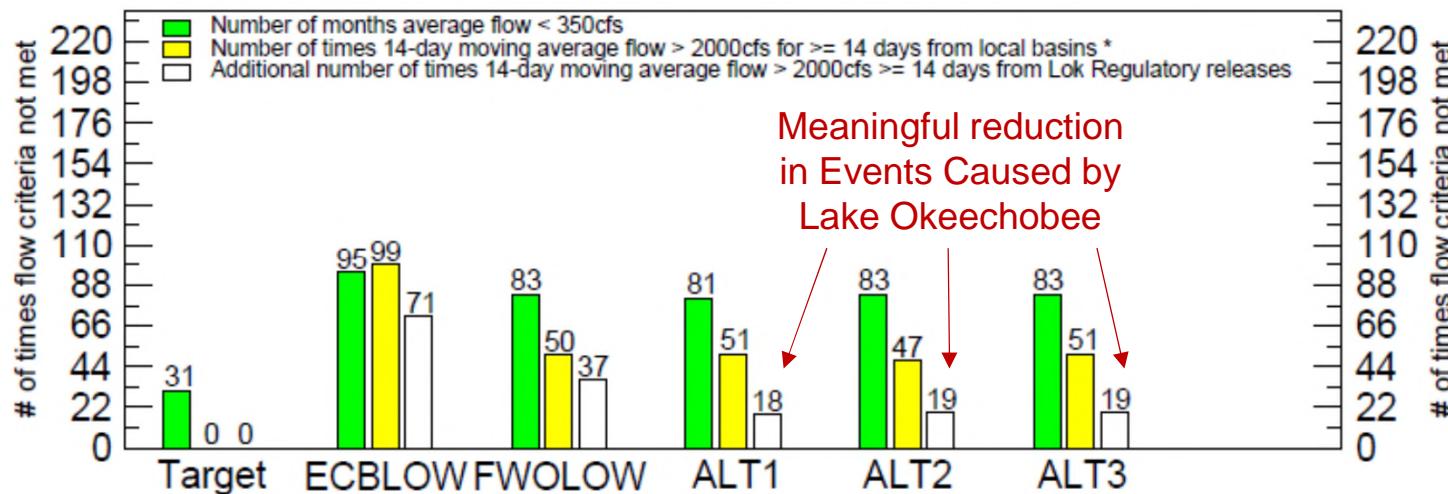
Examples of Available Water Budget Maps



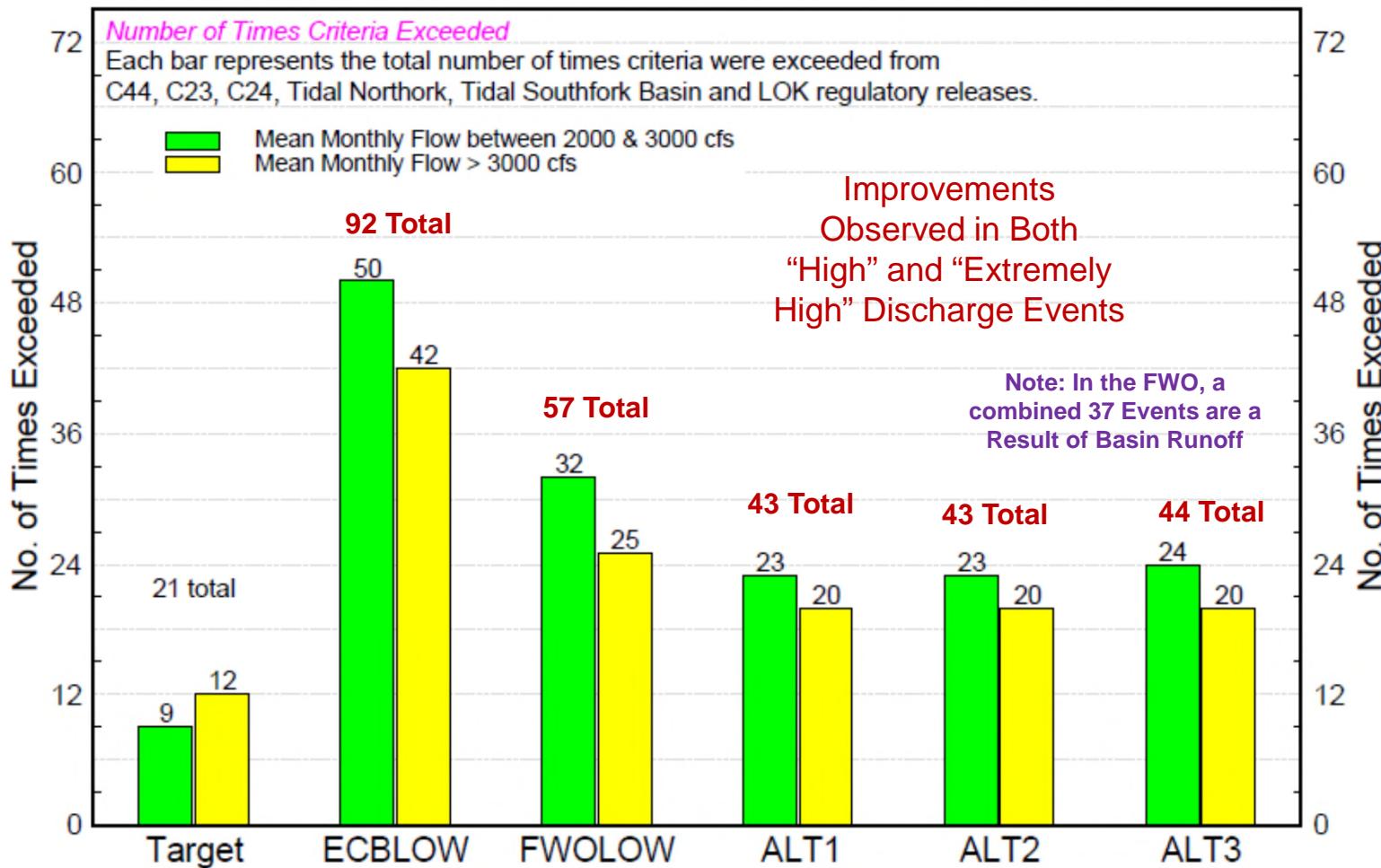
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Number of times Salinity Envelope Criteria NOT Met for the St. Lucie Estuary (mean monthly flows 1965 - 2005)



Number of Times St. Lucie High Discharge Criteria Exceeded (mean monthly flows > 2000 cfs from 1965 - 2005)



Note: A favorable maximum monthly flow was developed for the estuary (2000 cfs) that will theoretically provide suitable salinity conditions which promote the development of important benthic communities (eg. oysters & shoalgrass). Mean monthly flows above 3000 cfs result in freshwater conditions throughout the entire estuary causing severe impacts to estuarine biota.

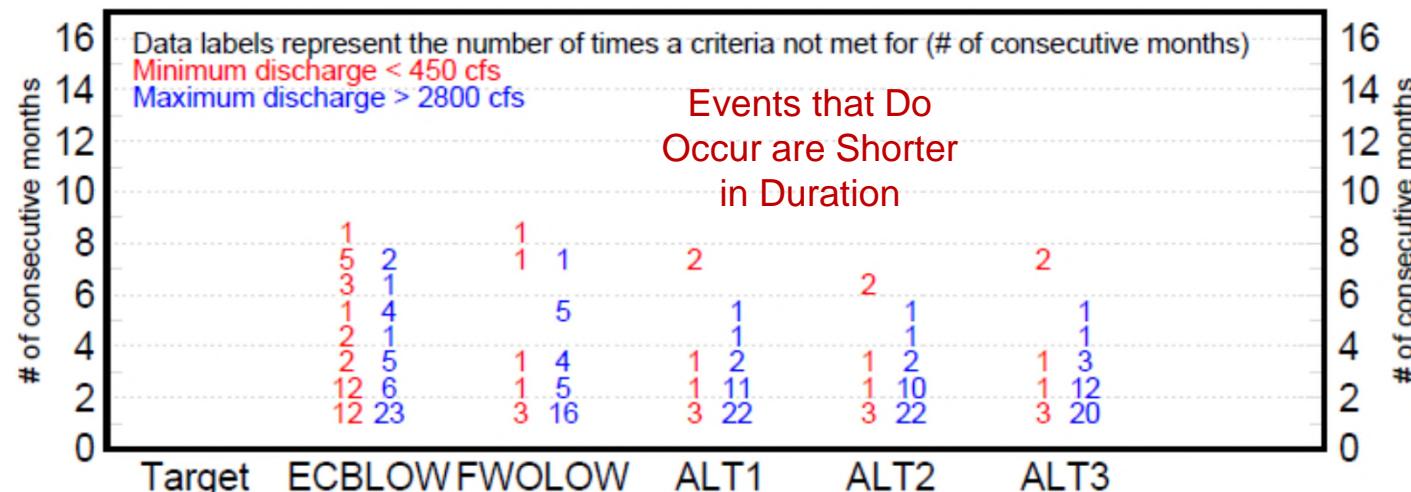
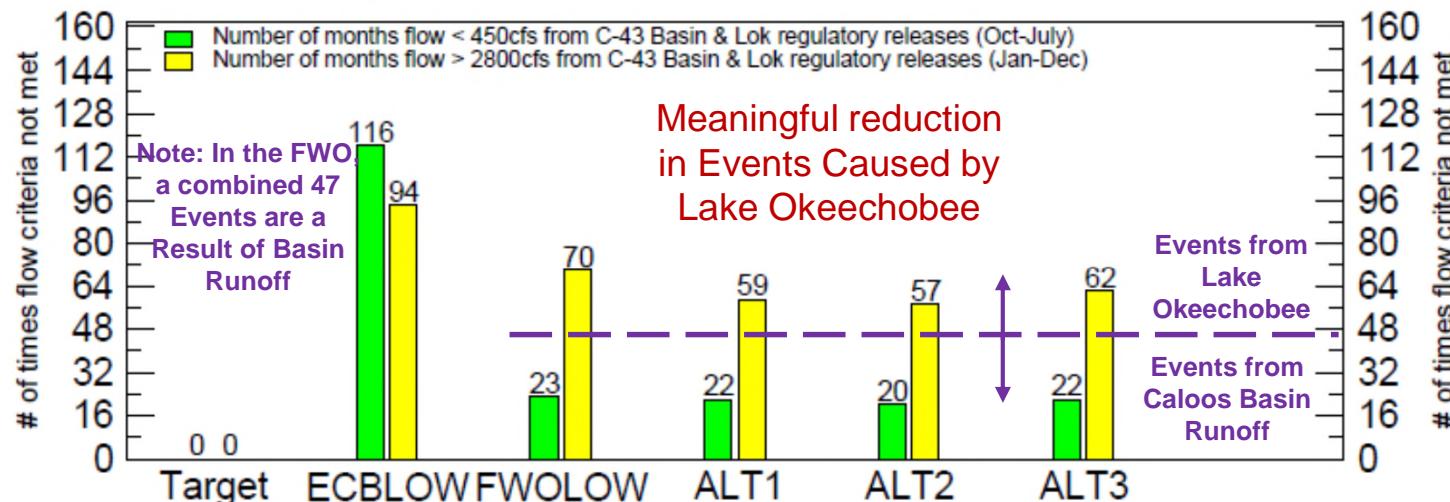
Run date: 03/07/17 11:10:36

RSMBN

Script used: estuary.scr, ID496

Filename: stluc_2000_flow_bar.out.agr

Number of times Salinity Envelope Criteria NOT Met for the Caloosahatchee Estuary (mean monthly flows 1965 - 2005)



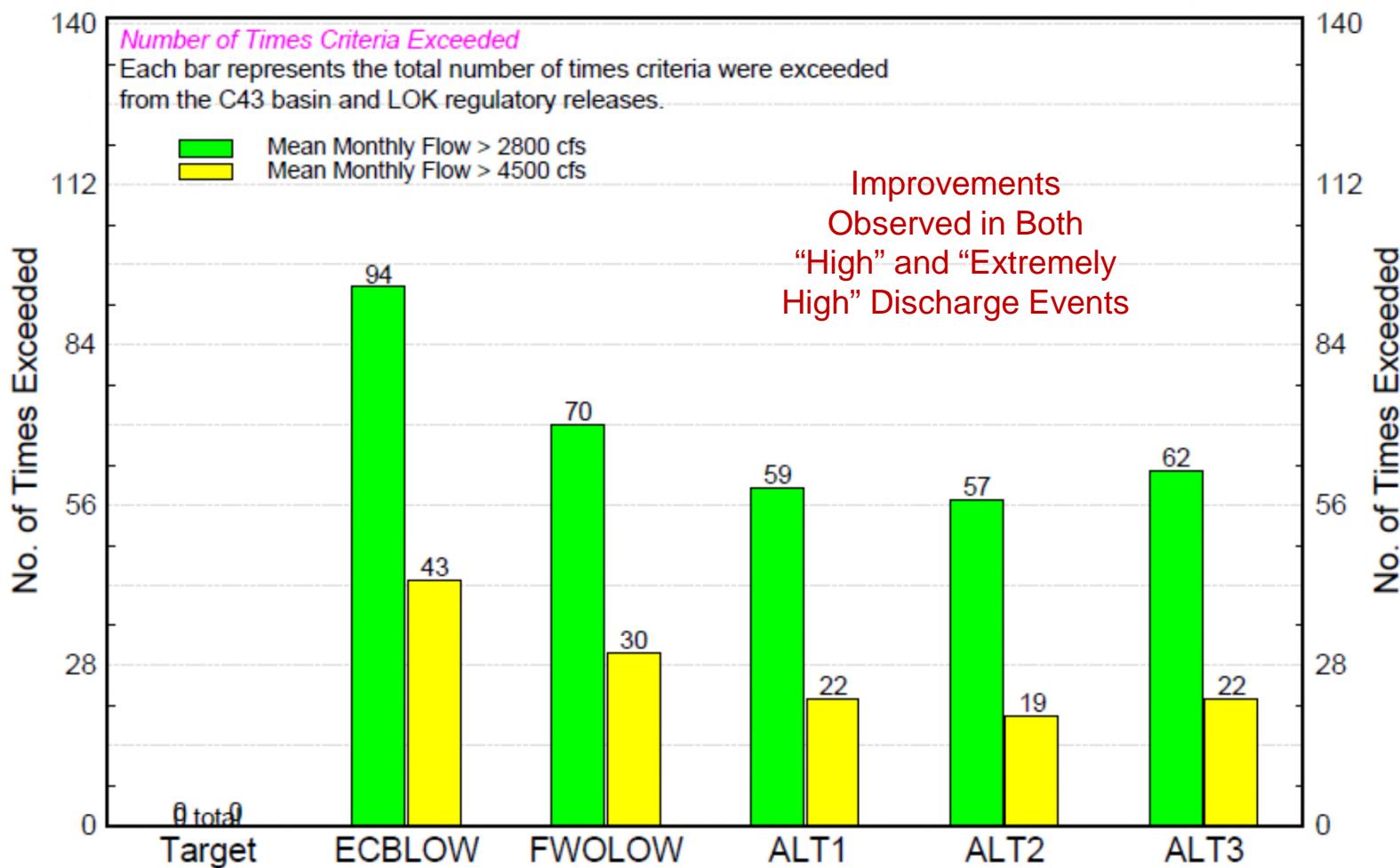
RECOVER Performance Measure

Run date: 03/07/17 11:10:36

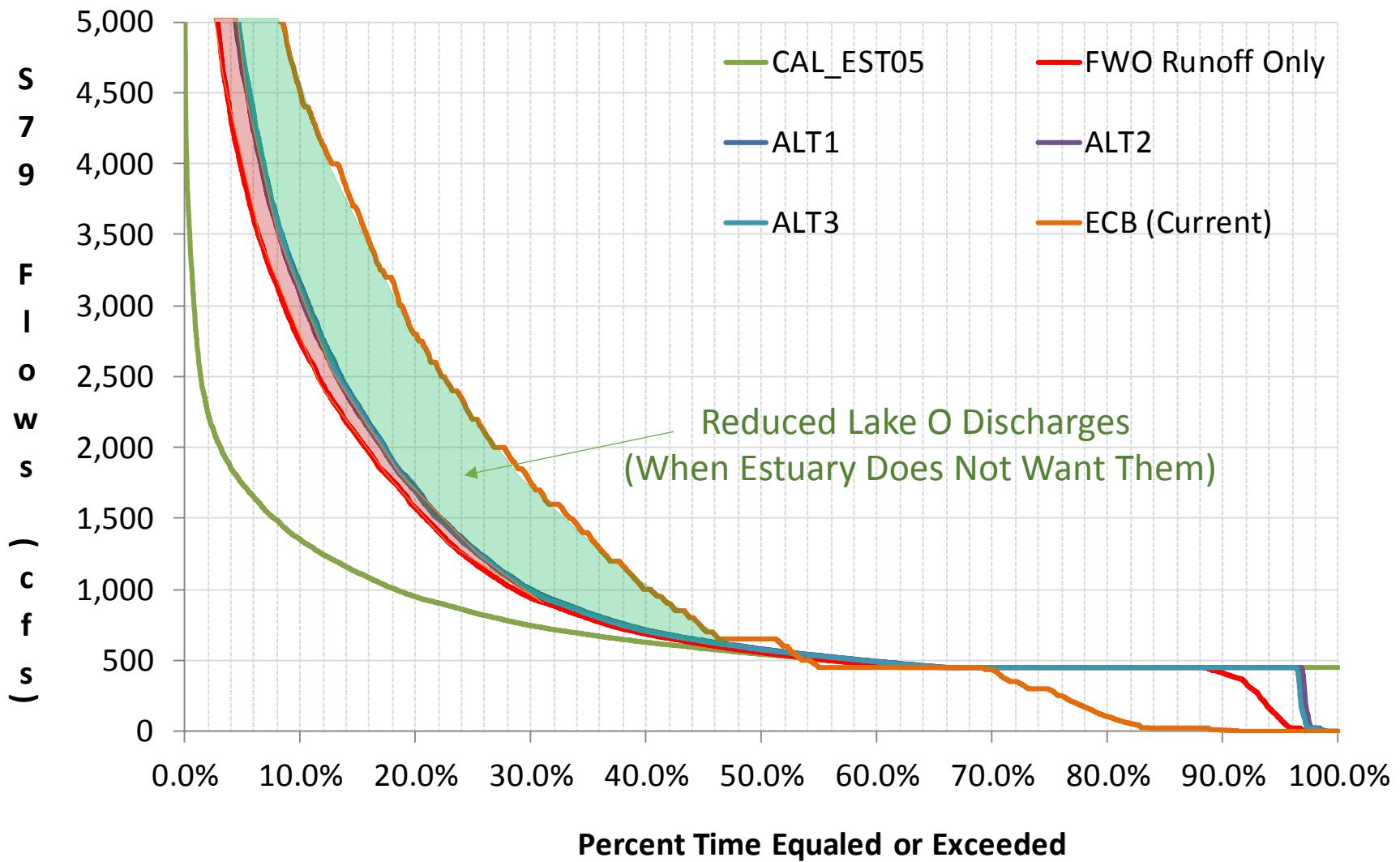
RSMBN

Script used: estuary.scr, ID496
Filename: caloos_salinity_flow_bar.out.agr

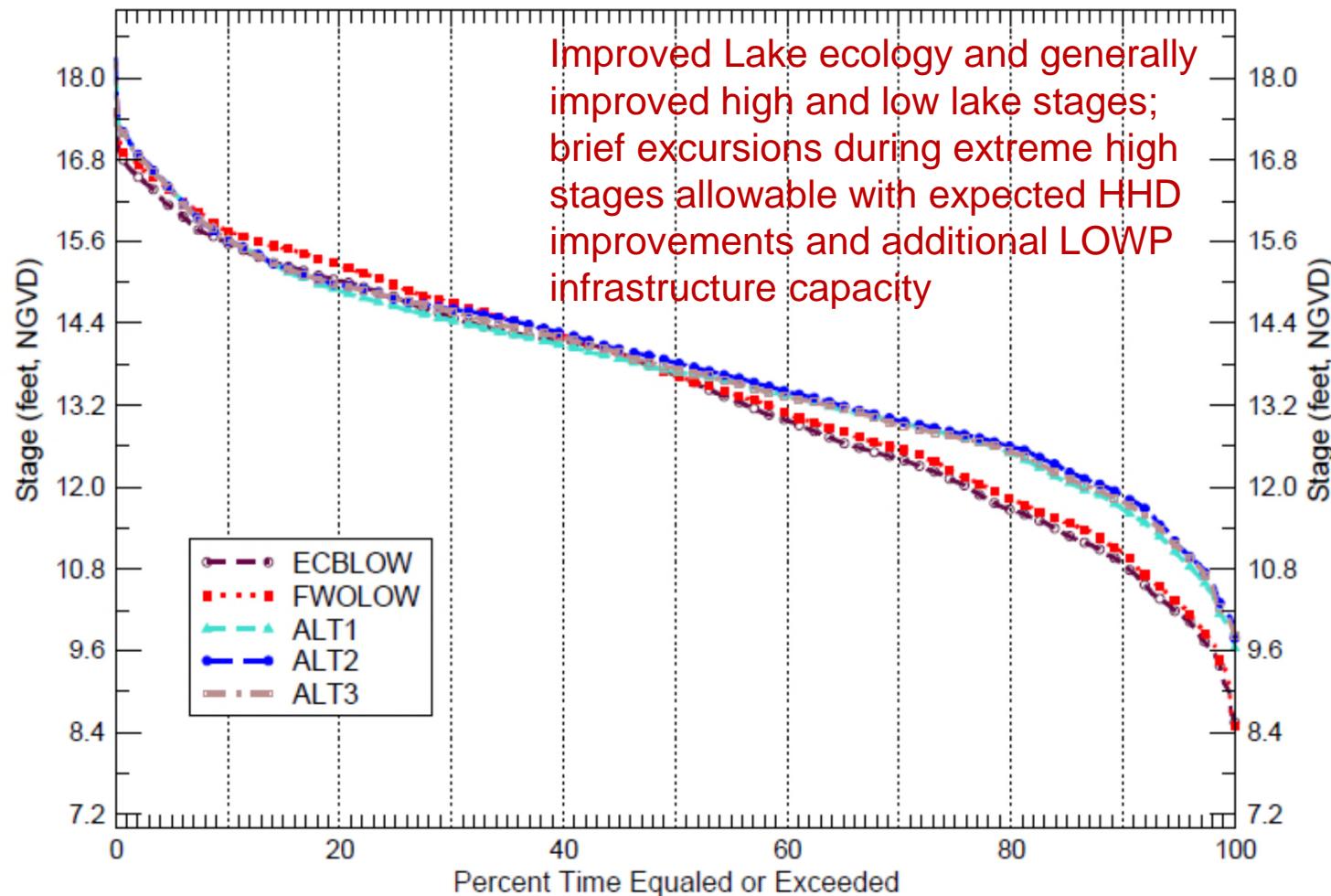
Number of Times Caloosahatchee Estuary High Discharge Criteria Exceeded (mean monthly flows > 2800 & 4500 cfs from 1965 - 2005)



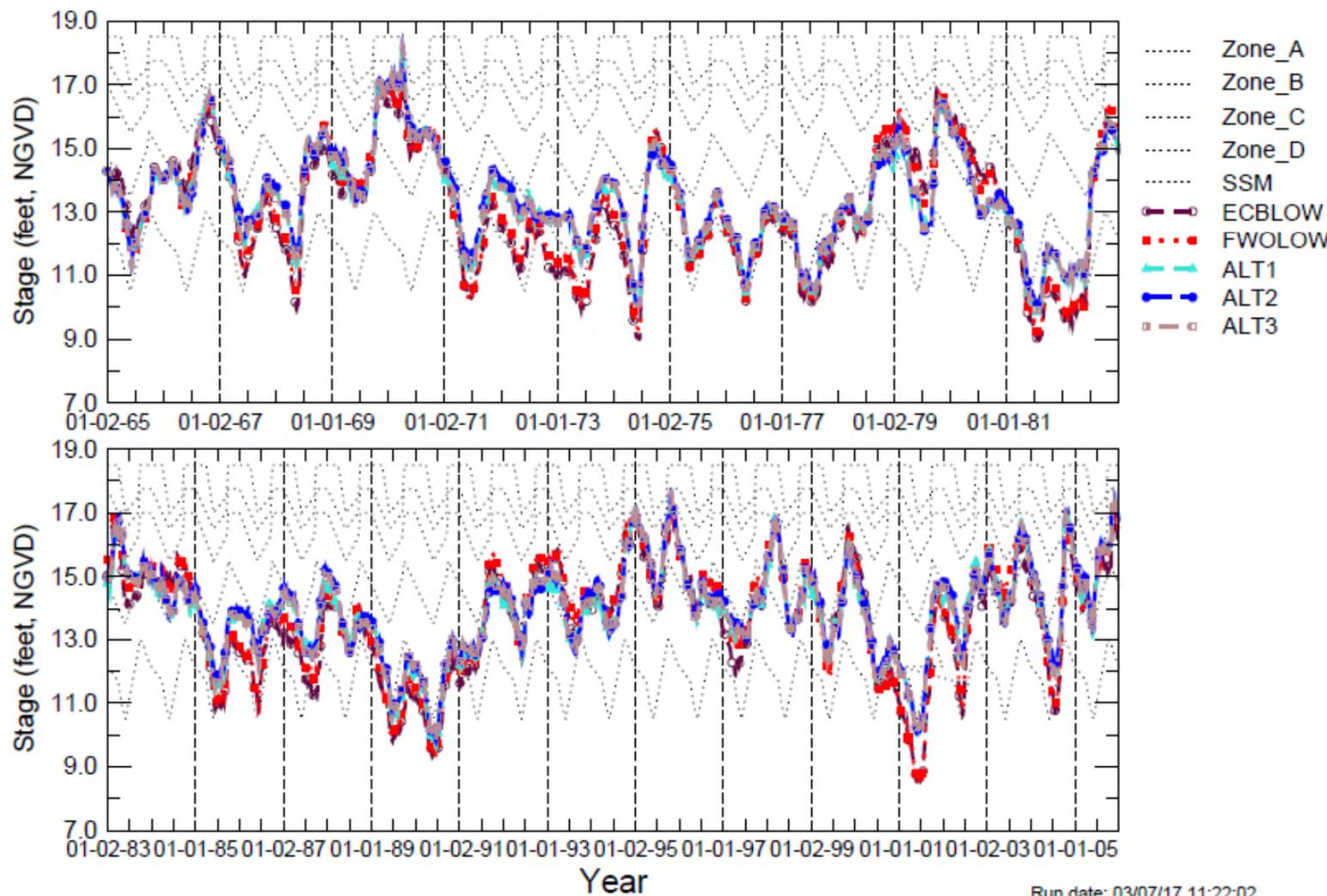
Flow Duration Curve for S79(cfs)



Stage Duration Curves for Lake Okeechobee



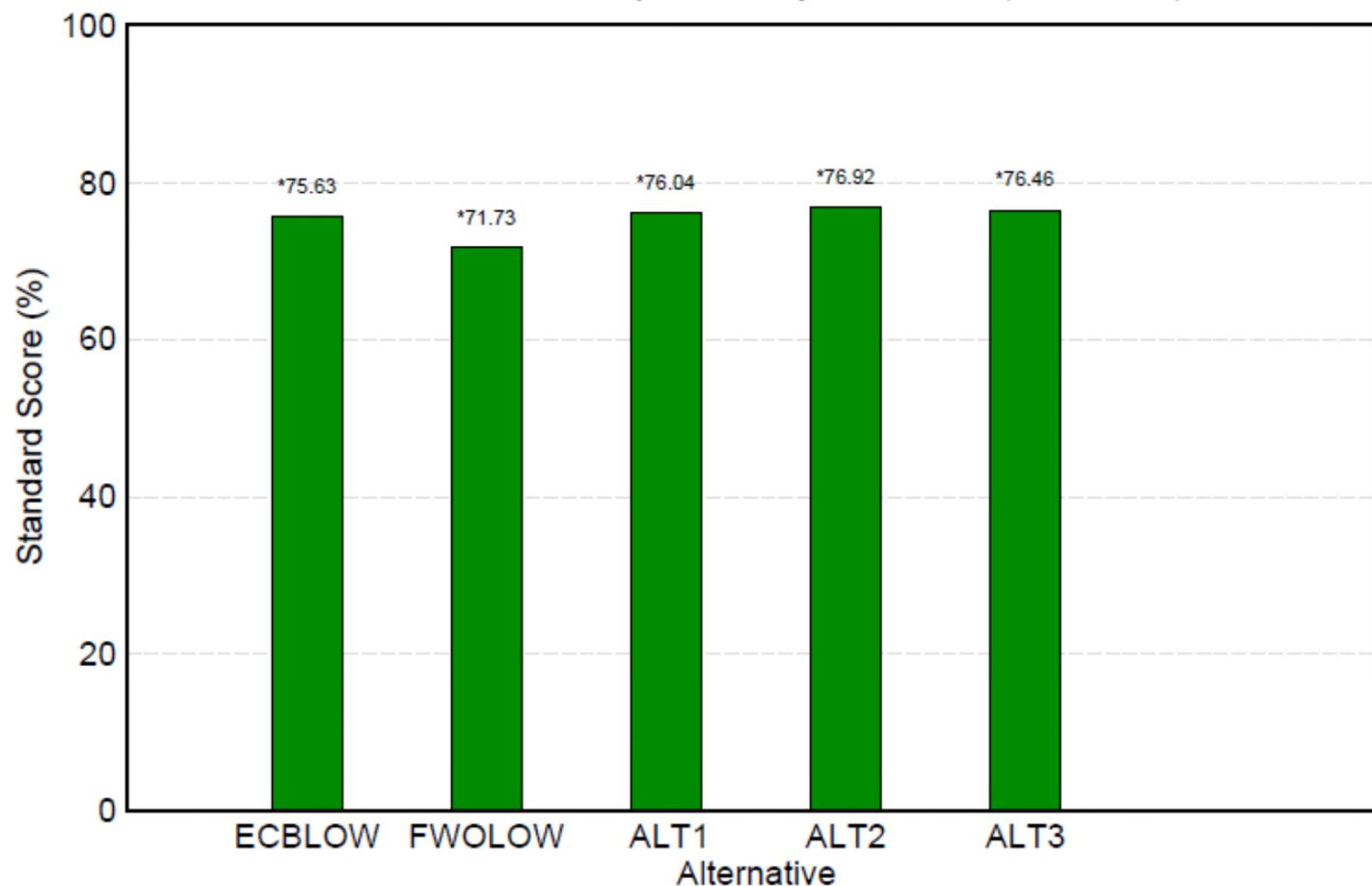
Stage Hydrographs for Lake Okeechobee



Higher Scores =
Improved Lake O.
Ecology

Lake Okeechobee Stage Envelope

Score Above Envelope - Weekly Calculation (1965-2005)



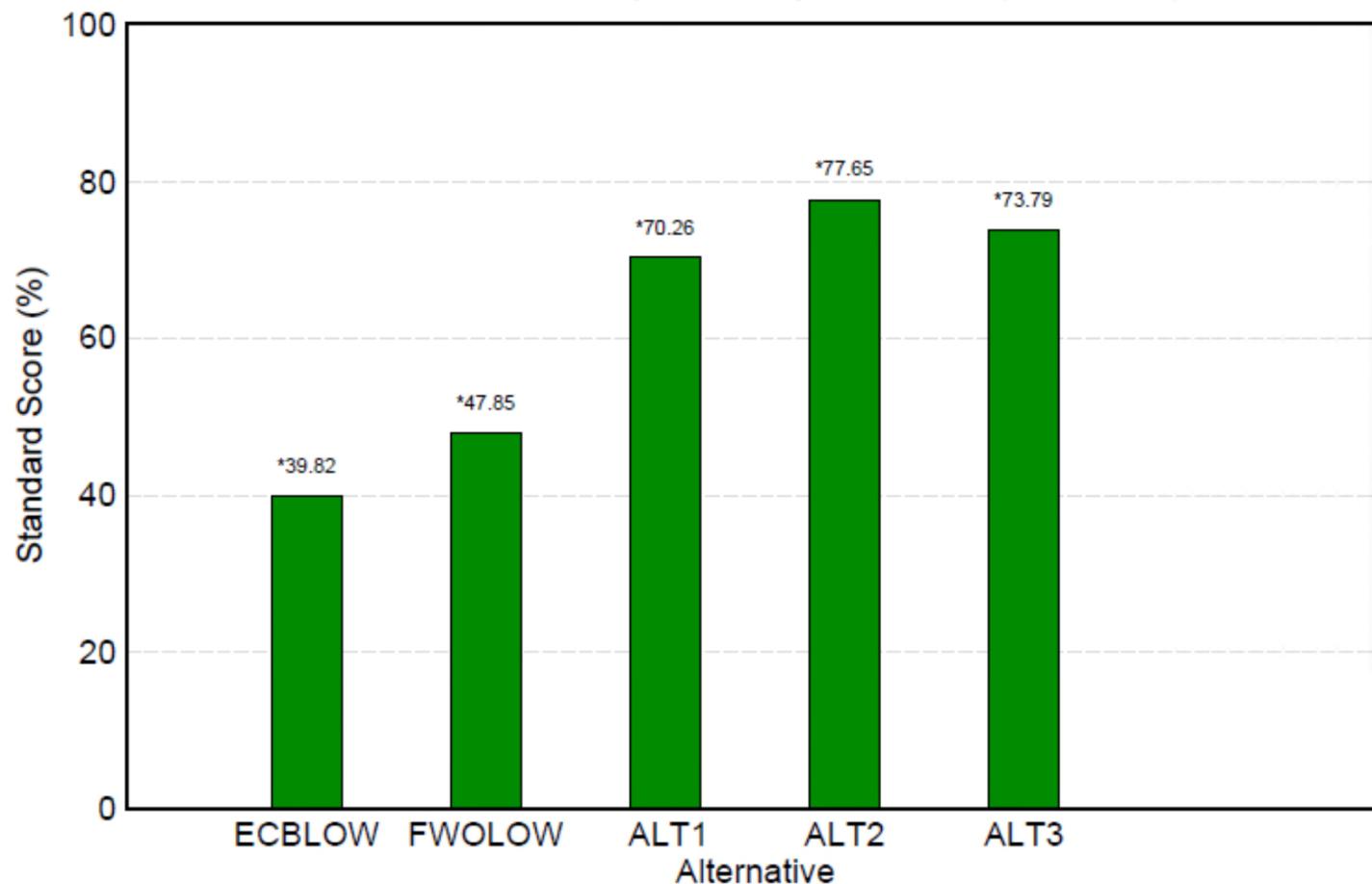
Note: A score of 0% is the worst score. The stage exceeds the envelope by 1 ft or more on average.
A score of 100% is the best score. The stage never exceeds the envelope.

Run Date: Tue Mar 7 11:20:57 2017
RSMBN
Script Used: lo_generator.scr (ID386)
Filename: lo3_weekly_high_annualized.agr

Higher Scores =
Improved Lake O.
Ecology

Lake Okeechobee Stage Envelope

Score Below Envelope - Weekly Calculation (1965-2005)



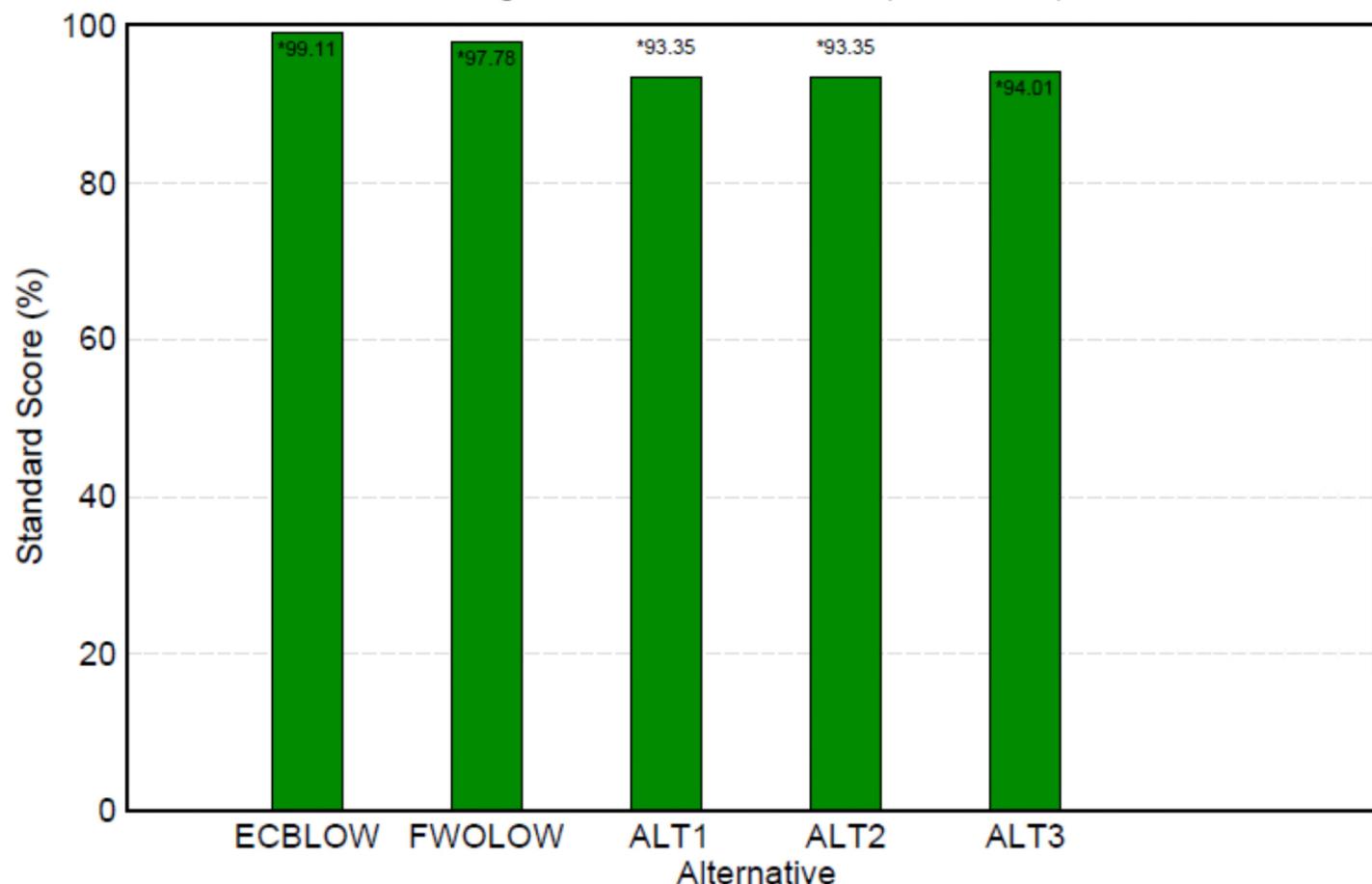
Note: A score of 0% is the worst score. The stage falls below the envelope by 1 ft or more on average.
A score of 100% is the best score. The stage never falls below the envelope.

Run Date: Tue Mar 7 11:20:57 2017
RSMBN
Script Used: lo_generator.scr (ID386)
Filename: lo3_weekly_low_annualized.agr

Higher Scores =
Improved Lake O.
Ecology

Lake Okeechobee Extreme High Lake Stage

Stage Above 17 Feet NGVD (1965-2005)



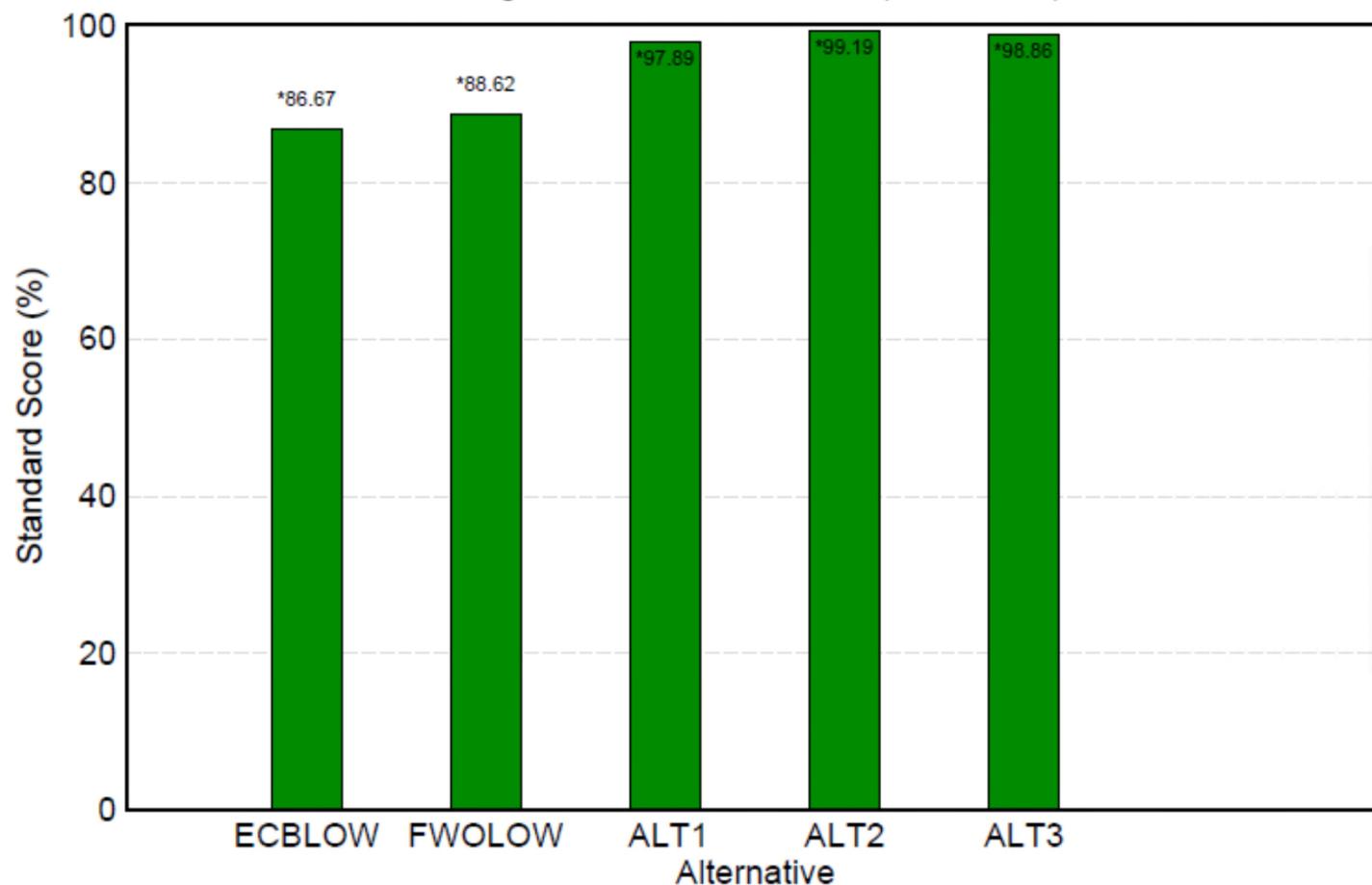
Note: A score of 0% is the worst score. The stage exceeds 17 feet for an average of 11 weeks per year or more.
A score of 100% is the best score. The stage never exceeds 17 feet.

Run Date: Tue Mar 7 11:20:57 2017
RSMBN
Script Used: lo_generator.scr (ID386)
Filename: lo2_weekly_high_lake_annualized.agr

Higher Scores =
Improved Lake O.
Ecology

Lake Okeechobee Extreme Low Lake Stage

Stage Below 10 Feet NGVD (1965-2005)



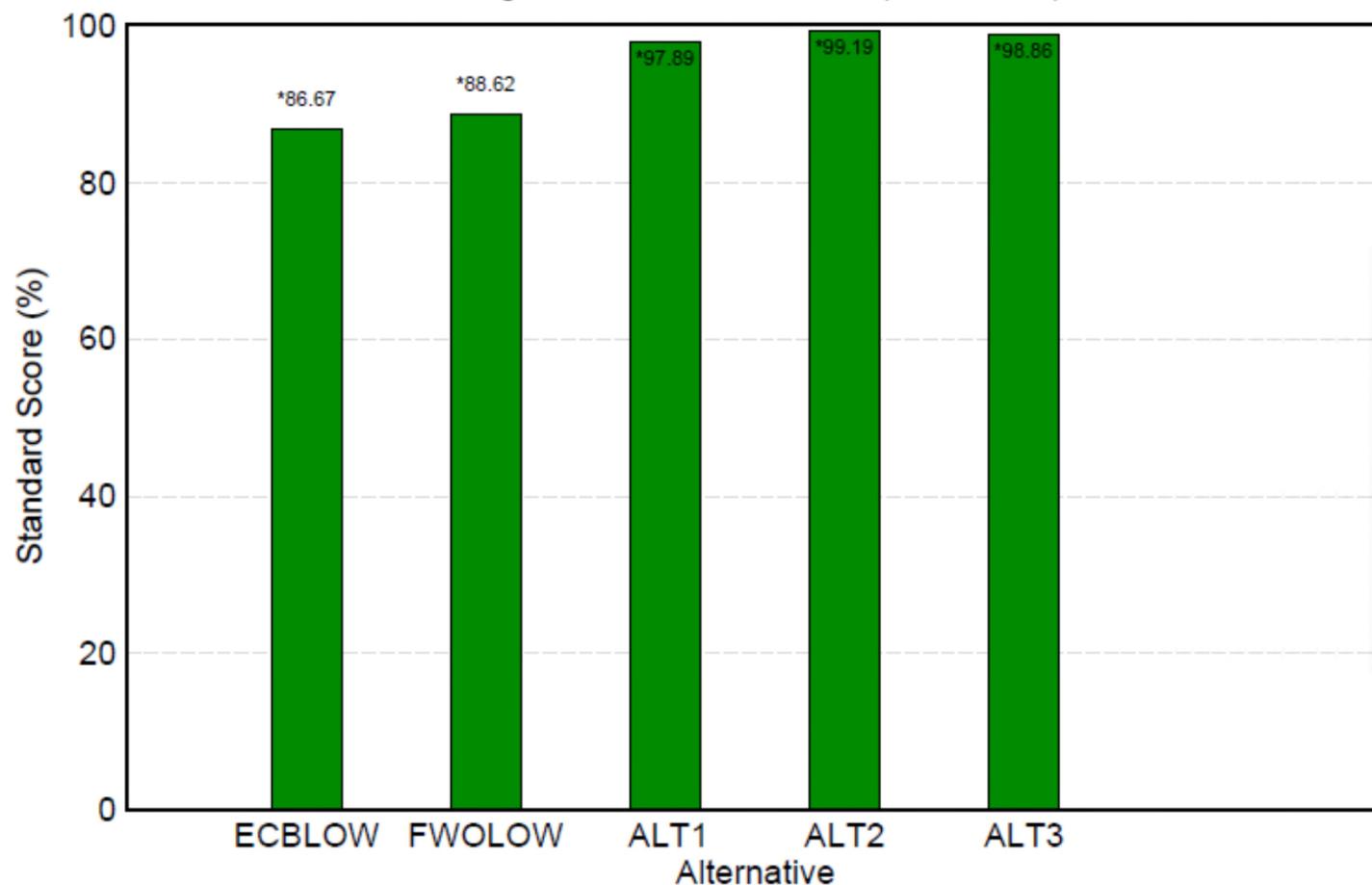
Note: A score of 0% is the worst score. The stage falls below 10 feet for an average of 15 weeks per year or more.
A score of 100% is the best score. The stage never falls below 10 feet.

Run Date: Tue Mar 7 11:20:57 2017
RSMBN
Script Used: lo_generator.scr (ID386)
Filename: lo1_weekly_low_lake_annualized.agr

Higher Scores =
Improved Lake O.
Ecology

Lake Okeechobee Extreme Low Lake Stage

Stage Below 10 Feet NGVD (1965-2005)



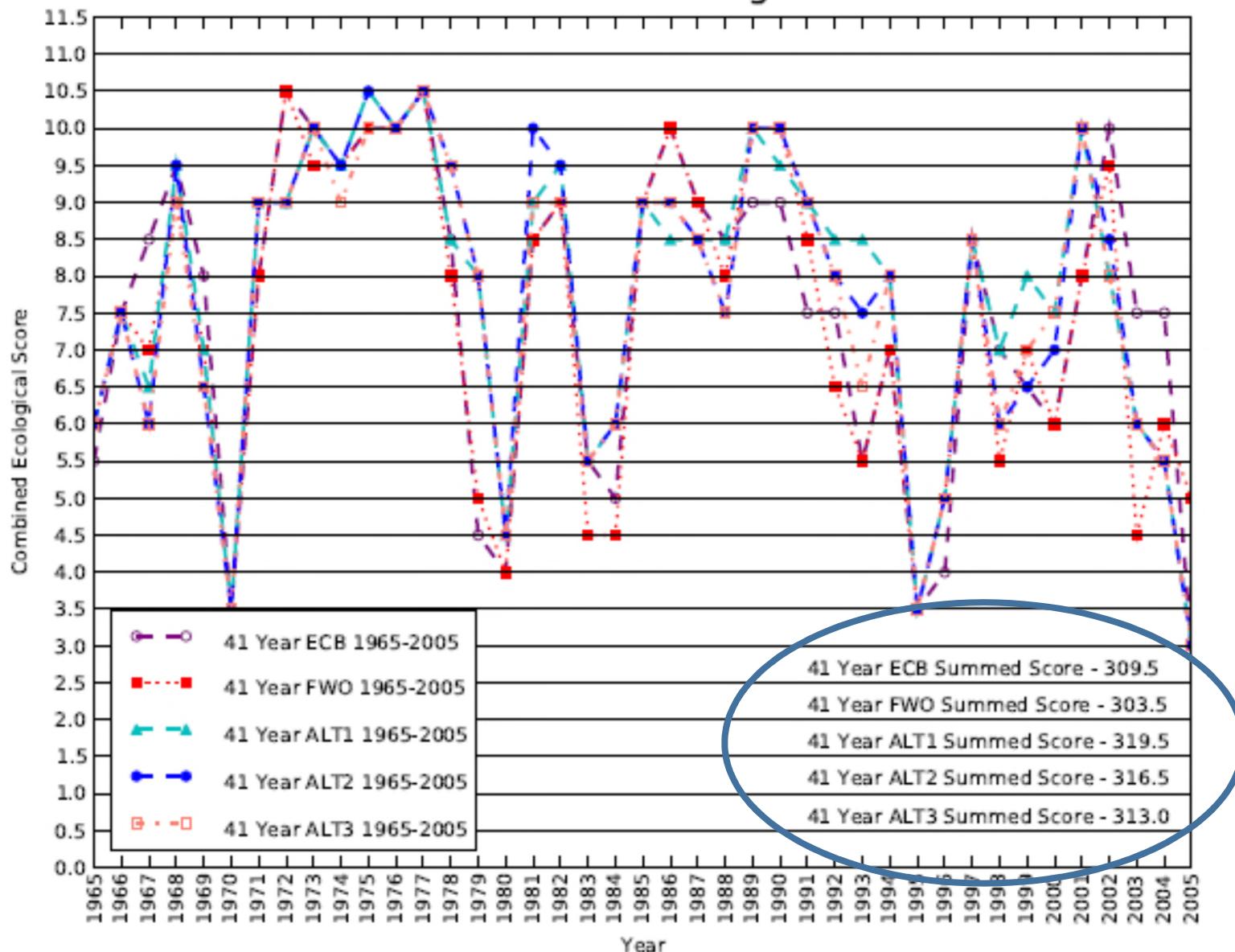
Note: A score of 0% is the worst score. The stage falls below 10 feet for an average of 15 weeks per year or more.
A score of 100% is the best score. The stage never falls below 10 feet.

Run Date: Tue Mar 7 11:20:57 2017
RSMBN
Script Used: lo_generator.scr (ID386)
Filename: lo1_weekly_low_lake_annualized.agr

Higher Scores = Improved

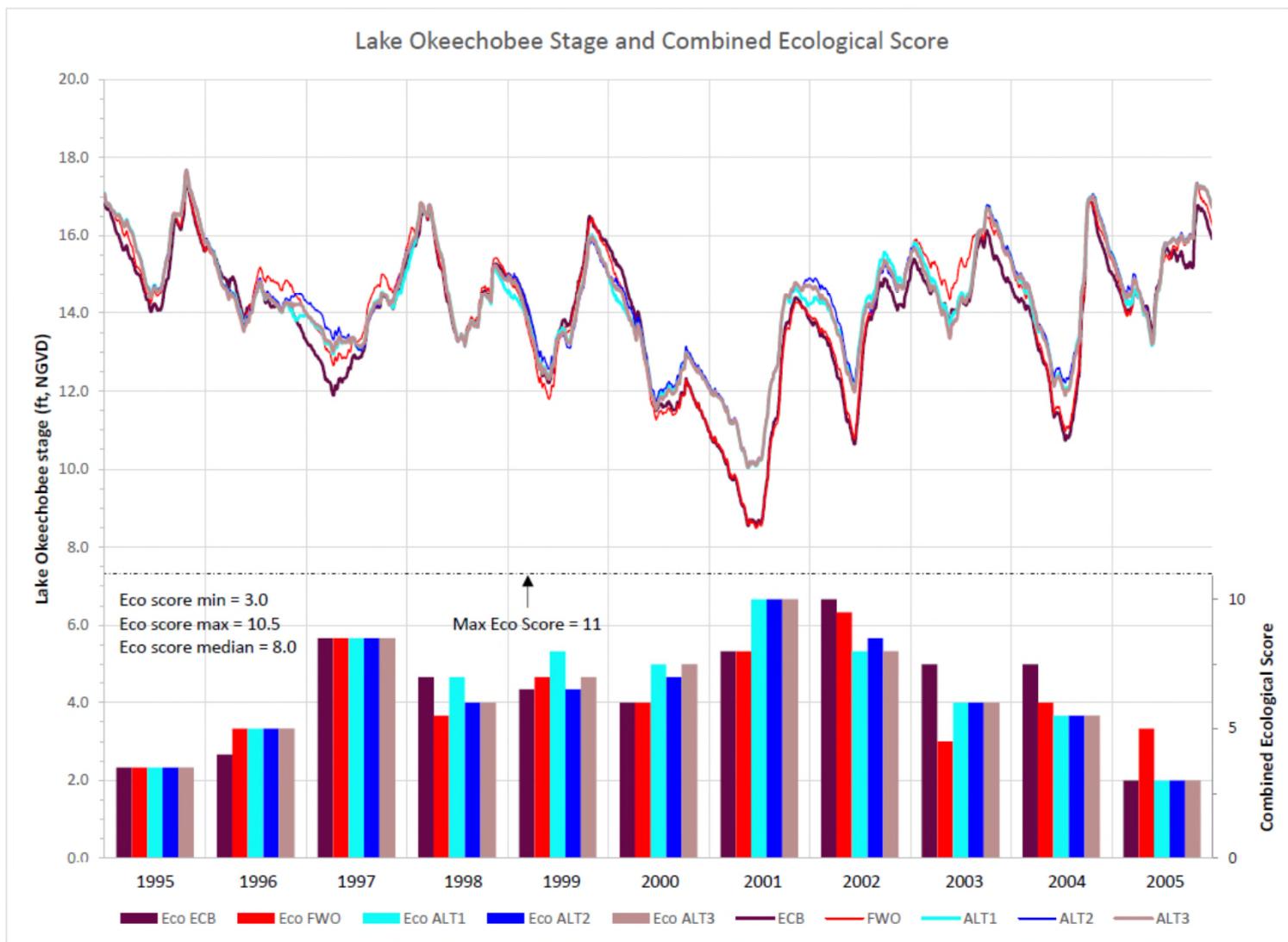
Lake O. Ecology

Combined Annual Ecological Scores



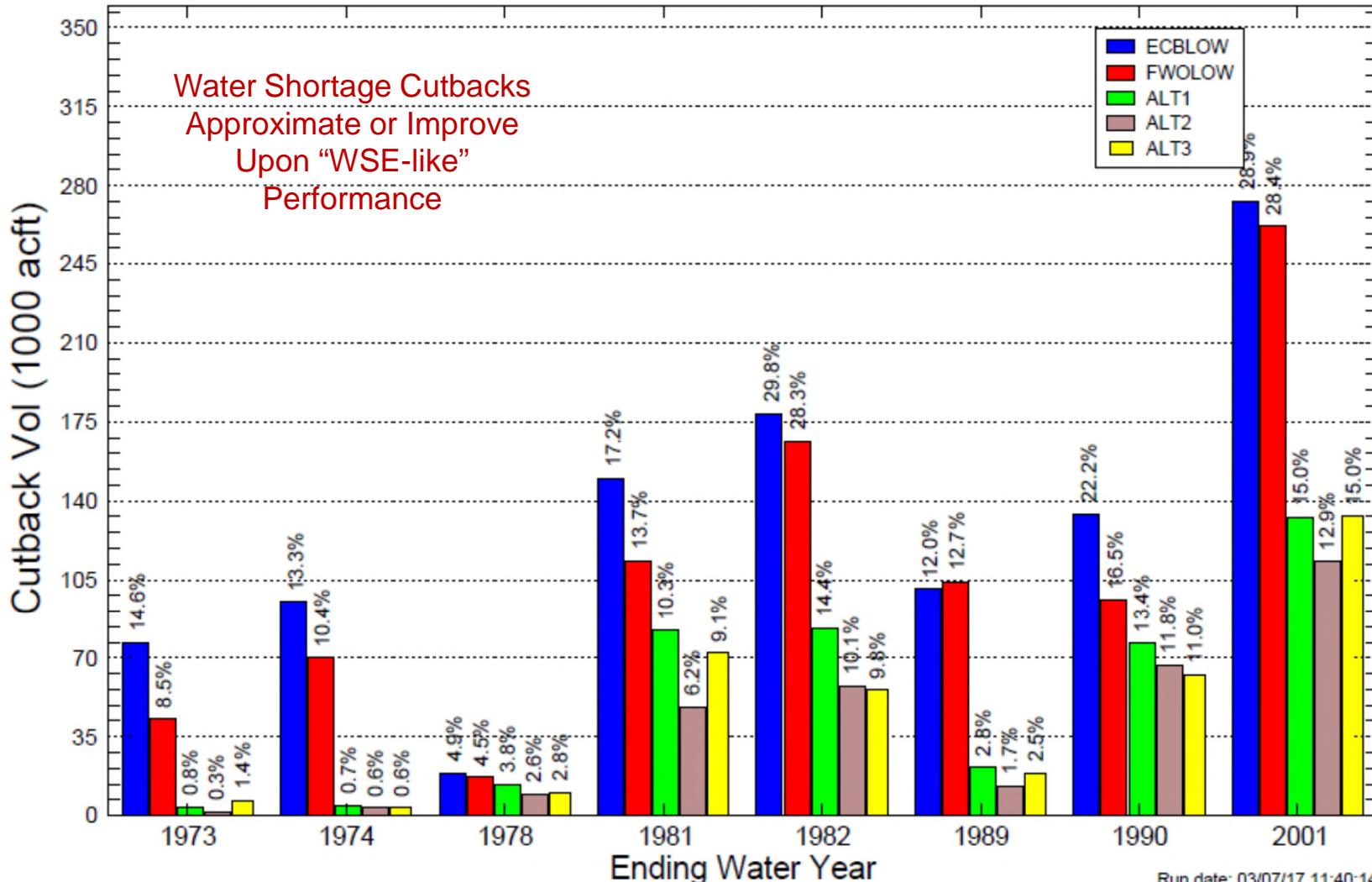
Additional Detail: Examining a Generally Wetter Period

Higher Eco Scores = Improved
Lake O. Ecology



Water Year (Oct-Sep) LOSA Demand Cutback Volumes

for the 8 Years in Simulation Period with Largest Cutbacks



Run date: 03/07/17 11:40:14

RSMBN RSMBN

Script used: losa_cutback_yrs.scr V370

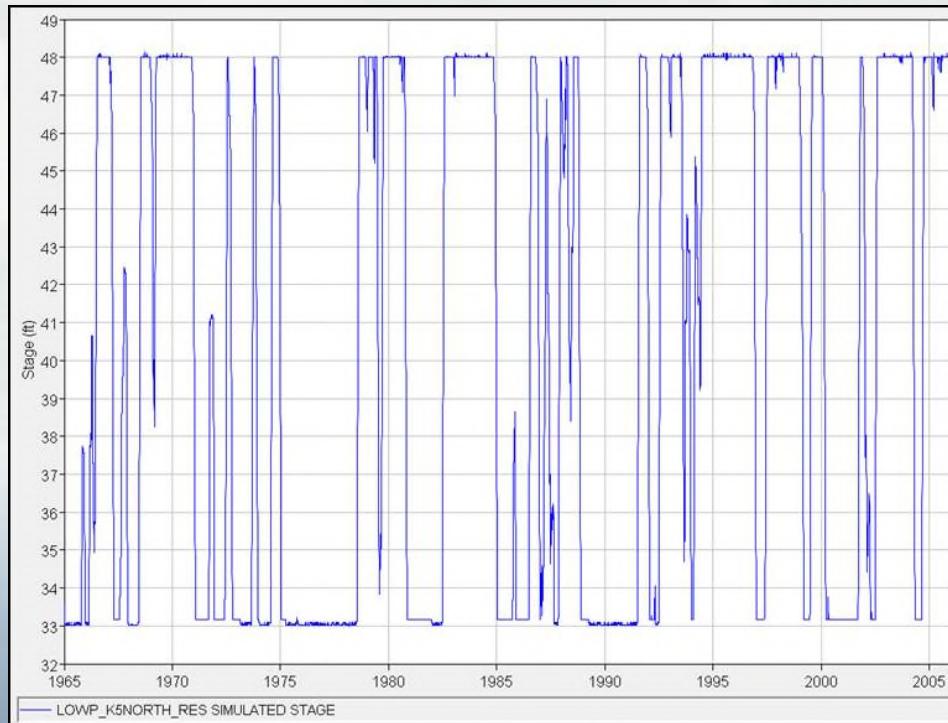
Filename: losa_cutback_yrs_bar.agr



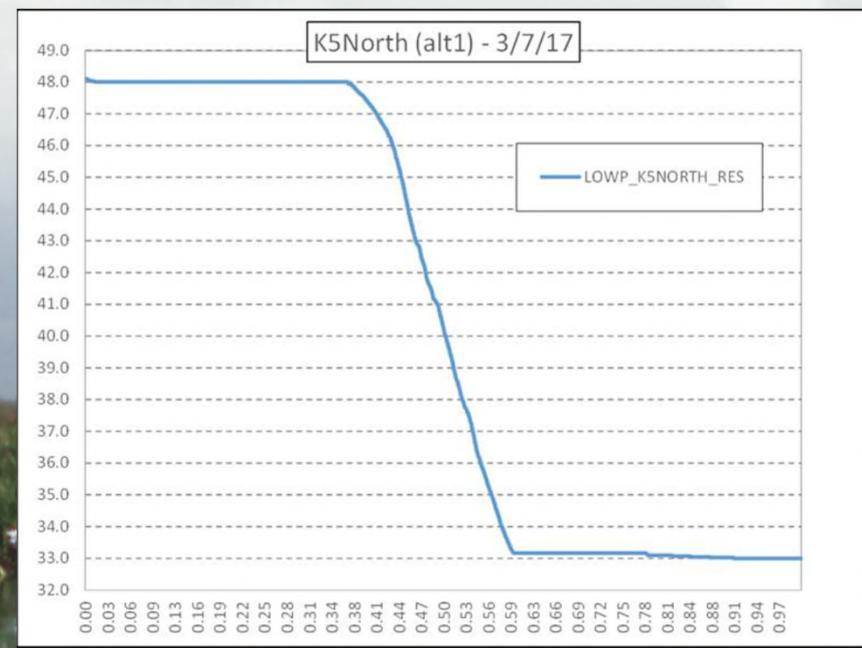
Example Performance of K05N Above Ground Reservoir for ALT1



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Frequent use of the above ground reservoir storage is evident across the RSMBN 1965-2005 simulation period.

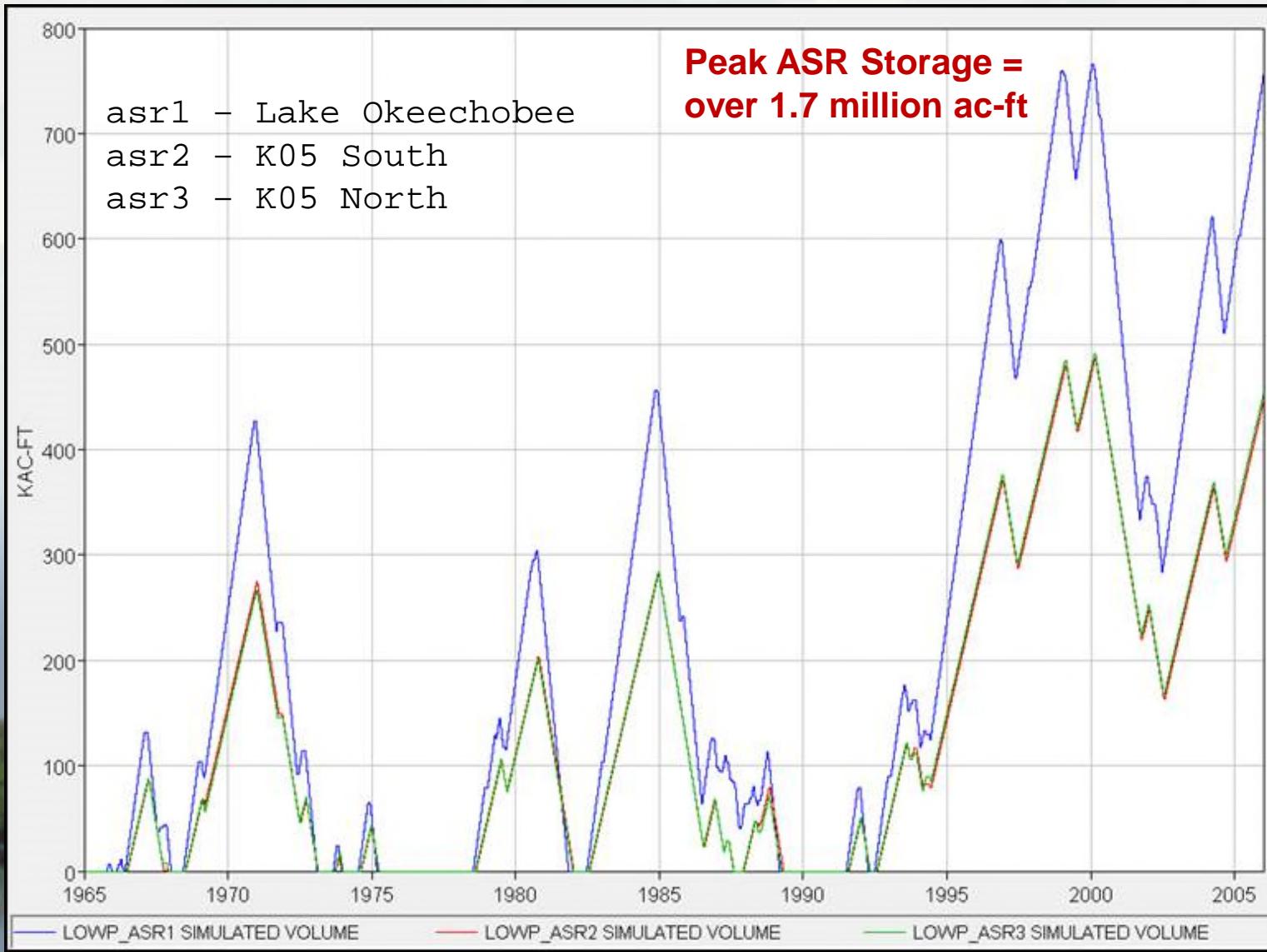




Example Aquifer Storage & Recovery Performance for ALT1



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Northern Estuaries Benefits Summary



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	Average Annual Lake O Regulatory Discharge (kac-ft)	% Estuary Regulatory Flow Reduction (relative to ECB)	Number of Years Lake O Causes a Damaging Event	% Estuary "Years with Impact" Reduction (relative to ECB)	Number of Months Lake O Causes a Damaging Event	% Estuary "Months with Impact" Reduction (relative to ECB)
St Lucie Estuary						
ECB	165		15		31	
FWO	126	24%	11	27%	20	35%
ALT1	82	50%	7	53%	9	71%
ALT2	80	52%	6	60%	10	68%
ALT3	84	49%	7	53%	10	68%
Caloosahatchee Estuary						
ECB	416		18		38	
FWO	257	38%	14	22%	23	39%
ALT1	140	66%	6	67%	9	76%
ALT2	136	67%	5	72%	7	82%
ALT3	139	67%	9	50%	12	68%

Results based on RSMBN modeling using a 41 year, 1965-2005 Period of Simulation

Note: Outcomes equal or exceed expectations from RESOPS Screening Analysis

How to Access Model Data



Available LOWP Modeling Data



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March 8th Release of LOWP Initial Alternatives Array

- ECB vs FWO vs ALT1 vs ALT2 vs ALT3 Performance Measures for RSMBN (e.g. Lake O., Northern Estuaries, LOSA)
- Other Indicators (e.g. water budgets,) for RSMBN
- ALT1, ALT2, ALT3 model output for RSMBN
- Minor updates to ECB and FWO from Feb 2, 2017 release
- DMSTA validation that flows south to Everglades meet water quality planning targets
- Spreadsheets summarizing operations optimization



Available LOWP Modeling Data (cont)



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- LOWP Modeling data is permanently archived and available on the CERPZone Data Archival Storage and Recovery (DASR) system.
 - Step by step instructions previously provided to PDT or available upon request.
- For a short time, data is also available via ftp at:

<ftp://ftp.sfwmd.gov/pub/LOWP/>

Name	Date modified	Type
CERP MMS Documents	7/1/2013 1:35 PM	File folder
Feasibility Studies and Plans	7/1/2013 1:35 PM	File folder
Models	7/1/2013 1:34 PM	File folder
non-CERP Projects	7/1/2013 1:34 PM	File folder
Pro Regs - Programmatic Regulations	7/1/2013 1:35 PM	File folder
PROJ 01 - Lake Okeechobee Watershed	11/9/2016 10:30 AM	File folder
PROJ 02 - Lake Istokpoga Regulation Sch...	7/1/2013 1:34 PM	File folder
PROJ 03 - Lake Okeechobee Aquifer Stor...	7/1/2013 1:34 PM	File folder
PROJ 04 a - Caloosahatchee River C-43 W...	7/1/2013 1:34 PM	File folder
PROJ 05 - C-43 Basin Aquifer Storage and...	7/1/2013 2:18 PM	File folder
PROJ 06 - Caloosahatchee Back-pumpin...	7/1/2013 1:34 PM	File folder
PROJ 07 - Indian River Lagoon - South	7/1/2013 2:18 PM	File folder
PROJ 08 - Everglades Agricultural Area St...	7/1/2013 1:34 PM	File folder
PROJ 10 - Big Cypress - L-28 Interceptor ...	7/1/2013 1:34 PM	File folder
PROJ 11 - Flows to NW and Central WCA ...	7/1/2013 1:34 PM	File folder



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- Walter Wilcox



Discussion

